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EDITORS

WILLIAM R. EVITT, for The Paleontological Society.

A. K. MILLER and W. M. FURNISH, for The Society of Economic Paleontologists and Mineralogists.

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Communications in regard to manuscripts or purely editorial matters should, be addressed to A. K. Miller & W. M. Furnish, Department of Geology, State University of Iowa, Iowa City, Iowa, or to William R. Evitt, Department of Geology, University of Rochester, Rochester 3, N. Y.

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NEW FUSULINIDS FROM THE PERMIAN OF WEST TEXAS

JOHN W. SKINNER AND GARNER L. WILDE
Humble Oil and Refining Company, Midland, Texas

ABSTRACT—Four new fusulinid species, one of which is the type of a new genus, are described from the Permian of West Texas. *Yabeina texana*, n. sp., *Reichelina lamarensis*, n. sp., and *Paradoxiella pratti*, n. gen., n. sp., were collected from the Lamar limestone member of the Bell Canyon formation; *Codonofusiella extensa*, n. sp., was found in the McCombs limestone member of the Bell Canyon formation. All were obtained from outcrops in or near McKittrick Canyon, Guadalupe Mountains, Culberson County, Texas. *Yabeina texana*, n. sp., is the first neoschwagerinid to be reported from West Texas, and the genus *Reichelina* has not been reported previously in the western hemisphere.

INTRODUCTION

FUSULINID foraminifers of the subfamilies Neoschwagerininae and Verbeekininae are widespread in the Middle and Upper Permian of southern Europe and Asia. They are also known to occur in northern Africa and in Australia and New Zealand. In North America they have been reported from an area extending from northern British Columbia to central Oregon. Up to the present, however, no members of these subfamilies have been reported from West Texas. Thus, the discovery of the species described in this paper extends the known geographic range of the Neoschwagerininae by more than 1500 miles.

The members of these two subfamilies have been commonly referred to as "Tethyan fusulinids" because their distribution closely follows the extent of the Permian Tethys seaway. Their stratigraphic significance has, in the past, been the subject of considerable speculation from which has arisen a diversity of opinion. Usually they have been found in isolated exposures or in structurally complex sequences whose stratigraphy is obscure. It has been difficult to correlate these sequences with those containing a non-Tethyan fusulinid fauna, because ordinarily there are no species common to the two.

The marine Permian strata of West Texas probably constitute the most nearly complete Permian section known in which the fusulinid faunas are dominated by non-Tethyan forms. The discovery of neoschwagerinids near the top of this sequence provides a valuable clue regarding the relative ages of these dissimilar faunas. In general, a very satisfactory zonation of the Permian of the southwestern United States can be made on the basis of fusulinid genera. The Wolfcampian faunas are dominated by species of the genera *Triticites*, *Pseudoschwagerina*, and *Schwagerina*; *Schwagerina* is the most common genus of the lower

Leonardian; the middle and upper Leonardian and the lower Guadalupian constitute the zone of *Parafusulina*; and the upper Guadalupian fusulinid faunas are dominated by species of *Polydiexodina*. Although the stratigraphic ranges of *Schwagerina*, *Parafusulina*, and *Polydiexodina* overlap somewhat, *Schwagerina* is unknown in the *Polydiexodina* zone in this area. This zonation appears to be generally applicable to all non-Tethyan sequences.

In southern Eurasia, however, this orderly succession of genera does not apply. For example, in Afghanistan *Schwagerina*, *Parafusulina*, and *Polydiexodina* may be found in the same piece of limestone, associated with such Tethyan genera as *Cancellina*, *Neoschwagerina*, *Afghanella*, and *Verbeekina*. Their mode of occurrence leaves no doubt that all are *in situ*. Elsewhere in the same region, both *Schwagerina* and *Parafusulina* are found in association with each of the Tethyan genera.

The Neoschwagerininae display a general upward succession through the Permian. *Cancellina*, the most primitive genus of this subfamily, first appears in beds that have been assigned to the lower part of the Middle Permian in Asia. It is directly followed by *Neoschwagerina* which, in turn, is joined by the more advanced genera such as *Afghanella*, *Sumatrina*, *Yabeina*, and *Lepidolina*. Unfortunately, this development is an addition rather than a simple upward replacement. Thus, *Cancellina* and *Neoschwagerina* are found with *Afghanella* in Afghanistan, *Neoschwagerina* occurs with *Yabeina* in Japan, and *Yabeina* is associated with *Lepidolina* in Cambodia. Thus, it appears that in the Tethys seaway the older elements of the faunas were not replaced by the younger ones, but continued upward in the section with them. This hypothesis is applicable to both the Tethyan and non-Tethyan genera. Evolution within a genus is of no great assistance; *Neoschwagerina minoensis* Deprat, which occurs with *Yabeina globosa* (Yabe) in the upper beds at Akasaka, Japan, is less complex than some of the other species of *Neoschwagerina* which are found lower in the same sequence.

The occurrence of *Yabeina* in the Lamar limestone indicates that at least the upper part of the Bell Canyon formation correlates with some part of the Upper Permian of Eurasia. The primitive character of the Lamar species suggests a correlation with the lower part of the Upper Permian.

Yabeina texana, n. sp., was found in the basal 15 feet of the Lamar limestone member of the Bell Canyon formation on the southeastern slope of the Guadalupe Mountains, Culberson County, Texas. The best locality is at the end of a small spur on the south side of Bear Canyon, one-half mile slightly north of west of Wallace E. Pratt's ranch house. It is about 200 yards southwest of a water well and pumping unit, and is in the NW/4 of the SE/4 of Sec. 14, Blk. 65, Twp. 1 S., T. & P. R. R. Survey. *Yabeina* occurs sparingly in the red-streaked, yellow, clastic limestone at the base of the Lamar, and in a banded, siliceous limestone which immediately overlies the clastic zone. It is accompanied by rather numerous specimens of *Codonofusiella extensa*, n. sp. The same species was also found

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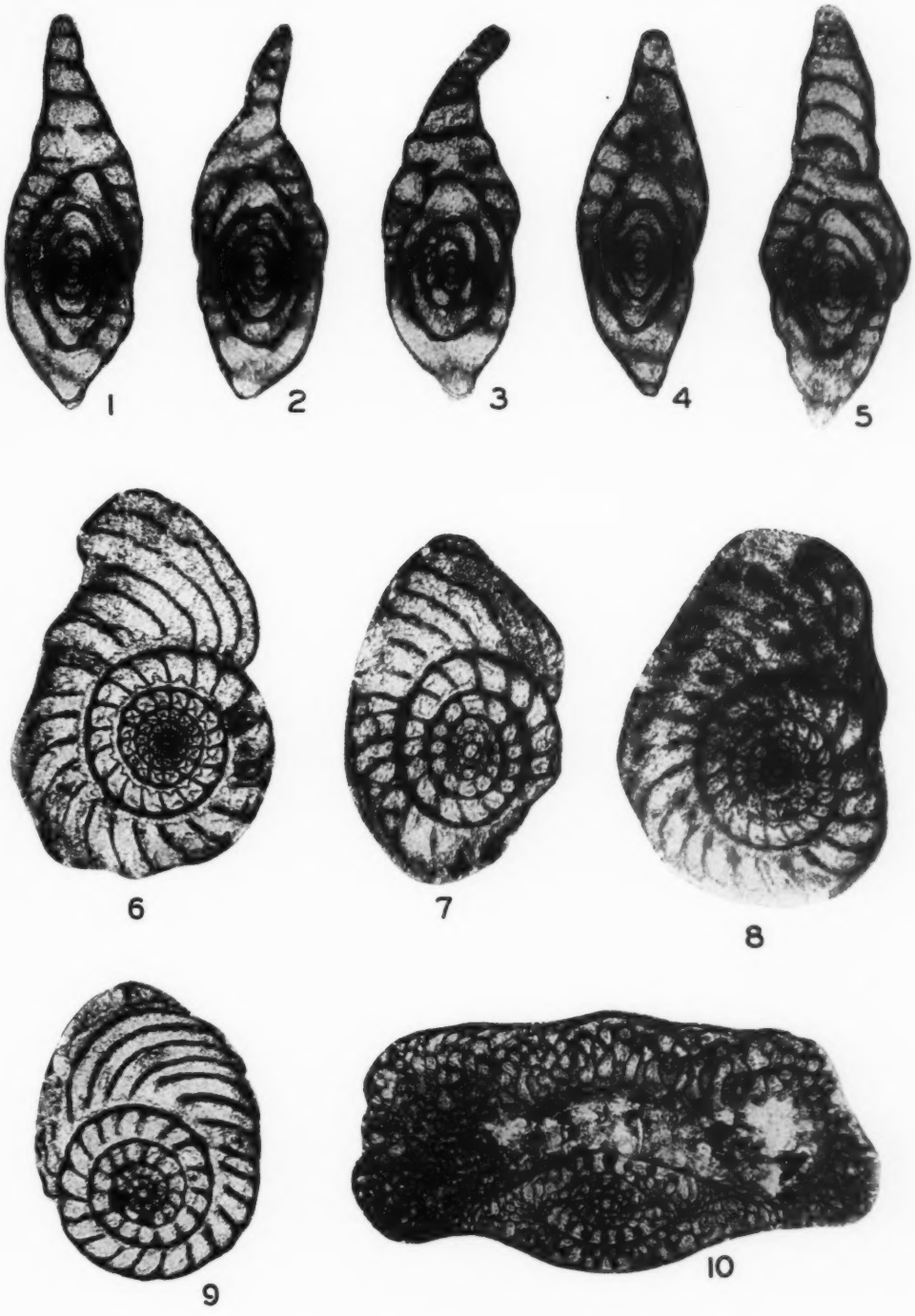
EXPLANATION OF PLATE 89

All figures are unretouched photographs.

FIGS. *1–9*—*Reichelina lamarensis* Skinner and Wilde, n. sp. *1*, axial section of the holotype, ×50; *2–5*, axial sections of paratypes, ×50; *6–9*, sagittal sections of paratypes, ×50. Lamar limestone member of Bell Canyon formation, Guadalupe Mountains, Culberson County, Texas.

10—*Codonofusiella extensa* Skinner and Wilde, n. sp. Axial section of the holotype, ×30. McCombs limestone member of Bell Canyon formation, Guadalupe Mountains, Culberson County, Texas.



Skinner & Wilde, Permian fusulinids from Texas

Skinner & Wilde, Permian fusulinids from Texas

a few feet above the base of the Lamar on the north side of Bear Canyon, due north of the pumping unit.

Erk (1941) described the genus *Reichelina* from the Upper Permian of the Bursa region in Turkey. He stated that it occurs in two zones, or facies. One of these contains *Cancellina*, *Neoschwagerina*, and *Sumatrina*, whereas the other carries *Polydiexodina*. In both zones *Reichelina* is accompanied by *Codonofusiella*.

Reichelina lamarensis, n. sp., is the first species of this genus to be reported from North America. Sporadic specimens are present throughout the Lamar limestone, but the species is abundant in a light-colored, cherty limestone 30 to 35 feet above the base of the Lamar at the top of a small hill just east of the road to McKittrick Canyon, and about one mile north of the junction of that road with the one leading from U. S. Highway No. 62 to the Pratt ranch house. This hill is known locally as Buck Hill. At this locality only the basal part of the *Reichelina* zone is present, but on the north side of the mouth of McKittrick Canyon there is a sequence of some 50 feet of similar limestones which contain this species in abundance. This sequence occupies the slope immediately below the upper Lamar cliff.

Codonofusiella extensa, n. sp., occurs in abundance in a small exposure of the McCombs limestone member of the Bell Canyon formation on the north side of the road leading into McKittrick Canyon. This locality is between the first and second points at which the road crosses the stream bed, and is just outside the mouth of the canyon. This species is also common in the basal part of the Lamar limestone in Bear Canyon, where it occurs with *Yabeina texana*, n. sp.

Paradoxiella pratti, n. gen., n. sp., is fairly abundant in a zone of thin-bedded, brown limestones 15 to 30 feet above the base of the Lamar limestone on the southwest side of Buck Hill. Sporadic specimens have been found in the overlying light-colored limestones at this locality associated with abundant *Reichelina lamarensis*, n. sp. A few specimens have been found in the basal Lamar on the north side of McKittrick Canyon drainage, just outside the mouth of the canyon.

The writers wish to thank the Humble Oil and Refining Company for permission to publish this paper, and to acknowledge their indebtedness to Mr. W. A. Rankin, of the Humble Geologic Research Section, who made all of the accompanying photographs.

SYSTEMATIC PALEONTOLOGY

Genus REICHELINA Erk, 1941

REICHELINA LAMARENSIS Skinner and Wilde, n. sp.

Plate 89, figures 1–9

Shell minute and lenticular, the axis of coiling being the shorter diameter. The inner whorls have a sharply rounded or bluntly angular periphery whereas that of the ultimate whorl is sharply angular. Mature individuals have 5 to 6 volutions and vary from 0.36 to 0.40 mm. in axial length and from 0.96 to 1.09 mm. in width. The final ⅓ to ½ volution is greatly expanded in height, with a corresponding increase in the length of the septa. The form ratio varies from 0.35 to 0.42, averaging 0.37.

The spirotheca is very thin and consists of a tectum and a diaphanotheca. In some

---

EXPLANATION OF PLATE 90

All figures are unretouched photographs.

FIGS. *1–5*—*Codonofusiella extensa* Skinner and Wilde, n. sp. *1–4*, axial sections of paratypes, ×30; *5*, tangential section of a paratype, ×50, showing the epithecal thickening of the septa in the equatorial region. McCombs limestone member of Bell Canyon formation, Guadalupe Mountains, Culberson County, Texas.

sagittal sections, a thin inner tectorium appears to be present, but axial sections show that this layer is confined to the central part of the shell, thinning and disappearing toward the poles. It is probably a thin layer of chomata deposit extending up the septa and across the tops of the chambers, rather than a true tectorium. The septa are thin and are composed of the same elements as the spirotheca. They are not fluted, but in the outer whorls are strongly convex anteriorly. Septal pores are common and usually appear as dark spots because of plugging with epitheca. The septa number 7 to 9 in the first whorl, 11 to 13 in the second, 12 to 15 in the third, 16 to 19 in the fourth, and 19 to 21 in the fifth.

The proloculus is minute and spherical, its outside diameter varying from 37 to 51 microns and averaging 42 microns. The tunnel is low and narrow. The tunnel angle varies from 17 to 18 degrees in the fourth whorl. The chomata are low and broad, extending laterally to the poles and joining across the floor of the tunnel.

In the following tables specimens A, B, and F are individuals in which the inflation begins near the end of the fifth whorl or in the sixth. In specimens C, D, E, and G the inflation begins near the middle of the fifth whorl.

Discussion.—Only two species, *Reichelina cribroseptata* Erk and *R. minuta* Erk, have been formally assigned to this genus. Both were described from the Upper Permian of Turkey. In addition, it appears certain that *Orobias mirabilis* Doutkevitch from the Upper Permian of the Pamir region should be placed in *Reichelina*. *Reichelina lamarensis*, n. sp., is the first member of the genus to be certainly identified from the western hemisphere, although it is possible that *Ozawainella delawarensis* Dunbar and Skinner may belong here. The excellent preservation of the latter seems to remove it from *Ozawainella* which is invariably poorly preserved even when the preservation of associated fusulinids is good. Thompson (1948) has suggested that this fact may indicate that *Ozawainella* possessed an original shell composition different from that of other fusulinids. *O. delawarensis* is the only described American species that might be confused with *R. lamarensis*. They differ in that the latter is smaller for the same number of volutions, its tunnel angle and form ratio are smaller, and the inflated portion of its ultimate whorl is proportionately higher and is narrower in the axial direction.

Occurrence.—*Reichelina lamarensis*, n. sp., is abundant in a light-colored, cherty limestone 30 to 35 feet above the base of the Lamar member of the Bell Canyon formation on the southwest side of Buck Hill, Culberson County, Texas. The zone constitutes the cap of the hill which is just east of the road leading into McKittrick Canyon and about a mile north of the junction of that road with the one which leads from U. S. Highway No. 62 to the Pratt ranch house. This species is also abundant in a sequence of some 50 feet of similar limestones which make up the middle part of the Lamar member on the north side of the mouth of McKittrick Canyon. In addition, sporadic specimens are found throughout the Lamar. The holotype and all but two of the paratypes were collected from the Buck Hill locality.

Genus CODONOFUSIELLA Dunbar and Skinner, 1937

CODONOFUSIELLA EXTENSA Skinner and Wilde, n. sp.

Plate 89, figure 10; plate 90, figures 1–5; plate 91, figures 1–6

Shell minute, consisting of a coiled body followed by an uncoiled flare. The coiled portion is fusiform, with sharply pointed poles, and consists of 4 to 5 whorls, the first 1 to 2 of which are discoidal and coiled askew to the later volutions. This part of the shell varies from 1.14 to 2.05 mm. in length and from 0.53 to 0.73 mm. in width. The form ratio varies from 2.17 to 2.90, averaging 2.54. The coiled body of the shell is followed by an uncoiled flare which expands laterally along the axis of coiling as well as tangentially. The septa of the flare increase in length, and the first few reach the body of the shell. Later ones, however, fail to reach the shell, and the distal margin of each septum curves back and is emplaced upon the face of the preceding one. The flare, although wide, is very thin

TABLE OF MEASUREMENTS (IN MILLIMETERS)

Specimen	Half Length						
	0	1	2	3	4	5	6
A	.018	.023	.034	.063	.093	.149	.206
B	.025	.034	.054	.085	.120	.173	—
C	.020	.025	.049	.087	.142	.186	
D	.021	.028	.047	.086	.131	.190	
E	.023	.032	.049	.087	.165	.199	
F	.021	.025	.039	.068	.107	.168	—
G	.018	.027	.044	.076	.149	.202	

Specimen	Radius Vector						
	0	1	2	3	4	5	6
A	.018	.031	.058	.092	.171	.275	.701
B	.025	.045	.079	.137	.207	.358	—
C	.020	.048	.085	.134	.265	.670	
D	.021	.048	.085	.155	.282	.612	
E	.023	.042	.076	.134	.235	.634	
F	.021	.042	.079	.131	.212	.379	—
G	.018	.049	.083	.128	.213	.747	

Specimen	Ratio HL/RV						
	0	1	2	3	4	5	6
A	1.00	0.74	0.59	0.68	0.54	0.54	0.29
B	1.00	0.76	0.68	0.62	0.58	0.48	—
C	1.00	0.52	0.58	0.65	0.54	0.28	
D	1.00	0.58	0.55	0.55	0.46	0.31	
E	1.00	0.76	0.64	0.65	0.70	0.31	
F	1.00	0.60	0.49	0.52	0.50	0.44	—
G	1.00	0.55	0.53	0.59	0.70	0.27	

Specimen	Thickness of Spirotheca						
	0	1	2	3	4	5	6
A	.007	.007	.008	.008	.011	.013	.014
B	.007	.010	.010	.010	.011	.013	—
C	.007	.008	.008	.010	.011	.013	
D	.007	.007	.010	.011	.011	.013	
E	.007	.007	.010	.011	.011	.013	
F	.007	.007	.008	.010	.011	.014	—
G	.007	.007	.008	.010	.011	.013	

Specimen	Tunnel Angle					
	1	2	3	4	5	6
A	—	18	18	18	26	—
B	—	18	18	17	26	—
C	—	—	—	18	23	
D	—	17	17	17	23	
E	—	—	18	18	20	
F	—	—	16	18	22	21
G	—	—	18	18	23	

(*Table continued on page 932*)

Specimen	Septal Count 1	2	3	4	5	6
H	7	12	14	17	19	—
I	9	13	14	17	—	
J	7	11	15	17	21	—
K	7	12	15	19	21	—
L	7	12	12	16	20	

and often curved in such a manner that the anterior face is concave. For this reason an axial section which intersects the periphery of the flare commonly passes in front of the greater portion of the face. The axial length of the flare is ordinarily about twice that of the coiled body of the shell. The shell, including the flare, is usually about 2.6 mm. in length and 1.7 mm. in width, but in one of our specimens these dimensions attain 3.5 mm. and 1.9 mm., respectively. The flare generally begins at the end of about 4½ volutions.

The spirotheca is thin, consisting of a tectum and diaphanotheca. In the fourth whorl its thickness averages 18 microns. The septa are composed of the same elements, with the addition of rather thick epithecal deposits on both the anterior and posterior faces in the central part of the shell. They are intensely fluted and the septal folds are high and narrow. Septal pores are numerous and cuniculi are present. The septa number 9 to 10 in the first whorl, 12 to 14 in the second, 17 to 20 in the third, and 24 to 29 in the fourth. The flare may possess as many as 30 septa.

The proloculus is minute and spherical, its outside diameter varying from 55 to 66 microns and averaging 62 microns. The tunnel is narrow and bordered by weak chomata in the first 3 volutions. In the flare it no longer pierces the distal margins of the septa but continues as a series of perforations about the same distance below the spirotheca as in the terminal part of the coiled portion of the shell. Here it is bordered by an epithecal thickening of the septa. It apparently continues to be narrow, and its course may be somewhat erratic since it is seldom seen in more than a few successive septa.

The following measurements apply only to the coiled body of the shell.

TABLE OF MEASUREMENTS (IN MILLIMETERS)

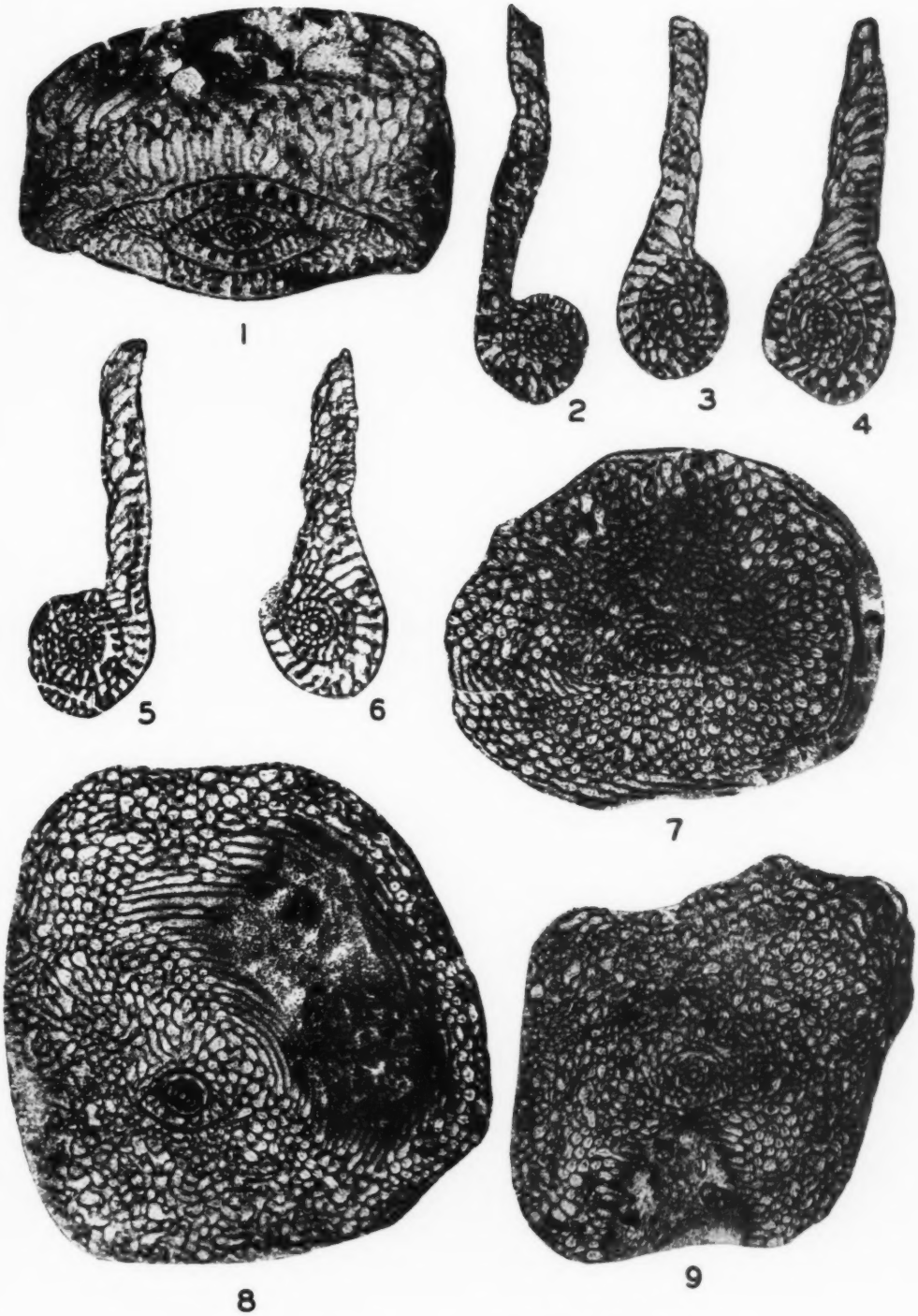
Specimen	Half Length 0	1	2	3	4	5
A	.033	.049	.082	.219	.499	—
B	.030	—	—	.203	.480	—
C	.033	—	—	.206	.460	—
D	.027	.038	.060	.200	.392	.822
E	.033	—	.121	.258	.567	—
F	.027	—	.123	.321	.696	
G	.033	—	—	.356	.701	—
H	.030	—	—	.192	.444	—

EXPLANATION OF PLATE 91

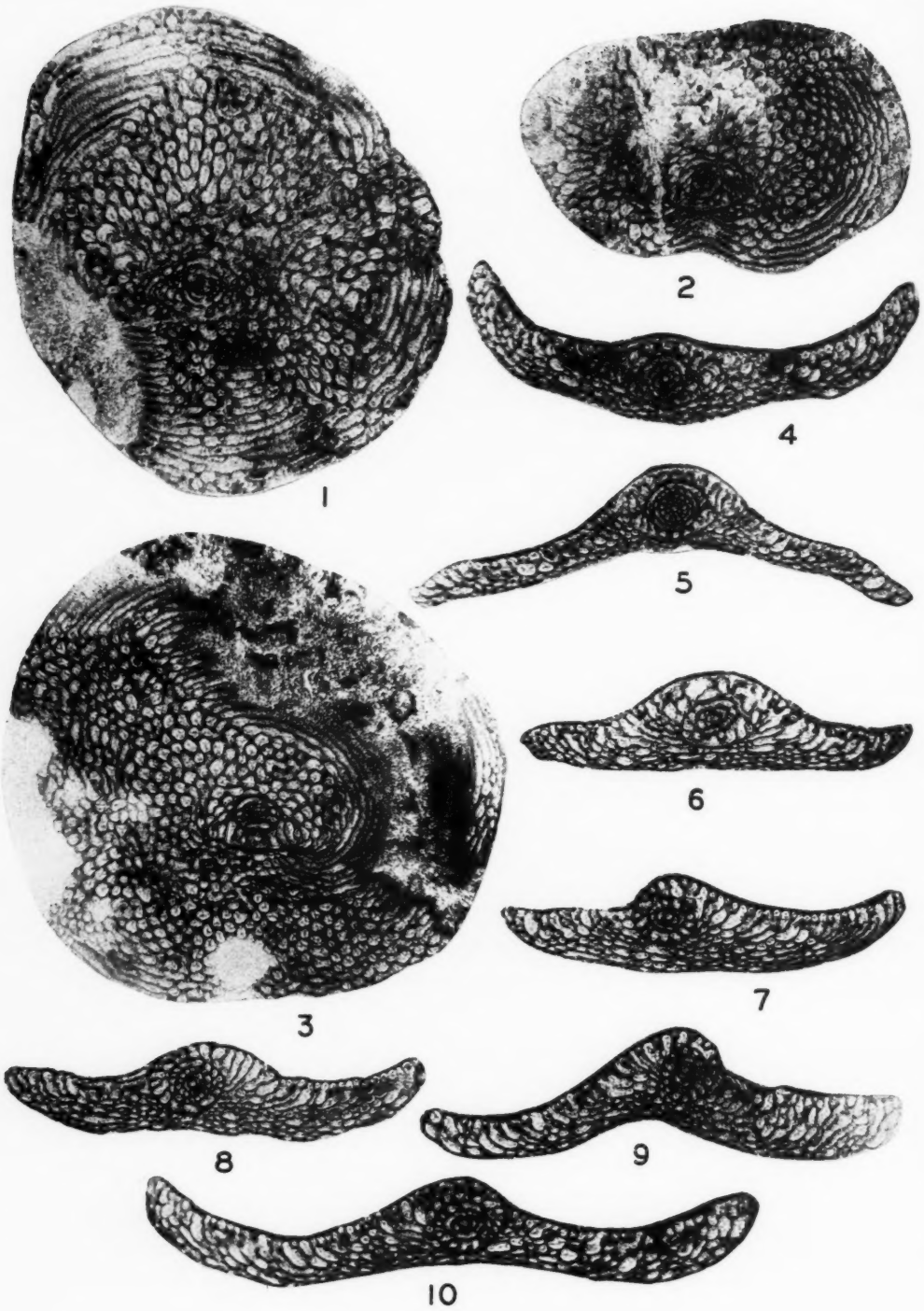
All figures are unretouched photographs.

FIGS. *1–6*—*Codonofusiella extensa* Skinner and Wilde, n. sp. *1*, axial section, ×30, of a specimen in which the lateral ends of the flare were broken off prior to fossilization; *2–6*, sagittal sections of paratypes, ×30. *1* is from the Lamar limestone; all others are from the McCombs limestone member of the Bell Canyon formation, Guadalupe Mountains, Culberson County, Texas.

7–9—*Paradoxiella pratti* Skinner and Wilde, n. gen., n. sp. *7*, horizontal axial section of the holotype, ×30; *8,9*, horizontal axial sections of paratypes, ×30. Lamar limestone member of Bell Canyon formation, Guadalupe Mountains, Culberson County, Texas.



Skinner & Wilde, Permian fusulinids from Texas



Skinner & Wilde, Permian fusulinids from Texas

Radius Vector

Specimen	0	1	2	3	4	5
A	.033	.063	.090	.148	.249	—
B	.030	—	—	.159	.266	—
C	.030	—	—	.137	.222	—
D	.027	.066	.107	.137	.197	.321
E	.033	—	.112	.175	.282	—
F	.027	—	.099	.181	.299	
G	.033	—	—	.186	.301	—
H	.030	—	—	.140	.241	—

Ratio HL/RV

Specimen	0	1	2	3	4	5
A	1.00	0.78	0.91	1.48	2.00	—
B	1.00	—	—	1.28	1.80	—
C	1.10	—	—	1.50	2.07	—
D	1.00	0.58	0.56	1.46	1.99	2.56
E	1.00	—	1.08	1.47	2.01	—
F	1.00	—	1.24	1.77	2.33	
G	1.00	—	—	1.91	2.33	—
H	1.00	—	—	1.37	1.84	—

Thickness of Spirotheca

Specimen	0	1	2	3	4	5
A	.011	.008	.008	.014	.020	—
B	.011	.008	.011	.013	.017	—
C	.010	.011	.011	.013	.018	—
D	.011	.011	.011	.013	.016	.021
E	.008	.013	.013	.016	.023	—
F	.011	.011	.013	.013	.016	
G	.011	.011	.013	.017	.017	—
H	.010	.010	.010	.013	.016	—

Tunnel Angle

Specimen	1	2	3	4	5
A	—	—	20	19	—
B	—	—	19	20	—
C	—	—	23	26	—
D	—	—	17	24	—
E	—	14	19	18	—
F	—	15	21	24	—
G	—	18	20	20	—
H	—	15	17	18	—

Septal Count

Specimen	1	2	3	4	5
I	—	14	19	27	—
J	—	—	19	27	—
K	—	14	19	28	—
L	—	13	19	29	—
M	—	—	17	24	—
N	—	—	20	—	

Discussion.—*Codonofusiella extensa*, n. sp., differs in several important respects from *C. paradoxica* Dunbar and Skinner, the only species of this genus previously described from this region. In *C. extensa* the coiled body of the shell is larger, has a larger form ratio, a greater number of whorls, and more sharply pointed poles. In addition, the septa are more intensely fluted, producing higher and narrower septal loops as seen in axial sections, and the epithecal thickening of the septa in the equatorial region is more pronounced. In the uncoiled flare the differences are even greater. In *C. paradoxica* the flare is essentially fan-shaped, the anterior margin being the greatest length, and the width is about equal to the diameter of the body of the shell. In *C. extensa*, however, the shape of the flare is more nearly that of a rectangle with rounded corners, the length along the axis being about the same as that along the anterior margin. The width of the flare, as measured in sagittal sections, is about twice the diameter of the body of the shell.

Occurrence.—*Codonofusiella extensa*, n. sp., is abundant in a small exposure of the McCombs limestone member of the Bell Canyon formation on the north side of the road into McKittrick Canyon, Guadalupe Mountains, Culberson County, Texas. This locality is between the first and second

EXPLANATION OF PLATE 92

All figures are unretouched photographs.

FIGS. *1–10*—*Paradoxiella pratti* Skinner and Wilde, n. gen., n. sp. *1–3*, horizontal tangential sections of paratypes, ×30; *4,5*, vertical axial sections of paratypes, ×30; *6*, inclined axial section of an immature specimen, ×30; *7–10*, sagittal sections of paratypes, ×30. Lamar limestone member of Bell Canyon formation, Guadalupe Mountains, Culberson County, Texas.

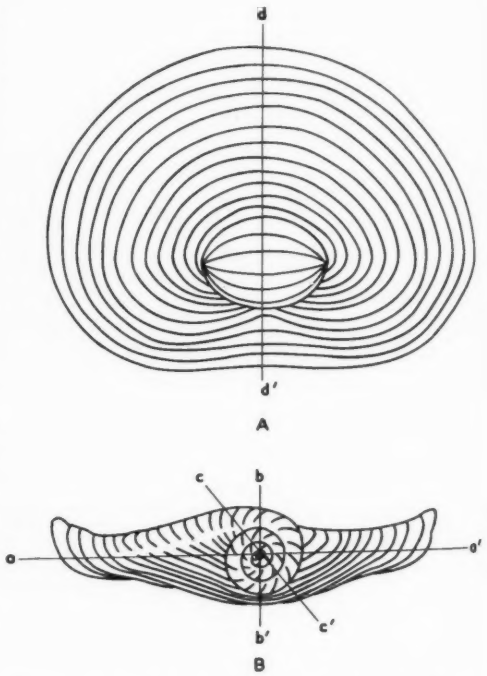
points at which the road crosses the stream bed, and it is just outside the mouth of the canyon. The exposure is immediately beside the road. This species is also common in the basal part of the Lamar limestone in Bear Canyon, where it occurs with *Yabeina texana*, n. sp.

Genus PARADOXIELLA Skinner and Wilde, n. gen.

Type species: *Paradoxiella pratti* Skinner and Wilde, n. sp.

Terminology.—Because of the peculiar mode of growth of this genus, it has been found necessary, for descriptive purposes, to employ terms which are not commonly applied to fusulinids. The shell consists of several planispirally coiled volutions, followed by an uncoiled, rapidly expanding flare which is virtually tangential to the final portion of the coiled body of the shell. The margin of the flare which is expanding in the same direction as the final portion of the coiled stage is regarded as the *anterior* margin. Conversely, the opposite side of the shell is considered to be *posterior*. The surface of the flare which is covered by the spirotheca is regarded as the *dorsal* surface, whereas the opposite surface, which is covered by the septa, is considered to be *ventral*. The poleward extensions of the axis of coiling are regarded as being *lateral* in direction. An axial section normal to the dorsal surface is termed a *vertical* axial section, whereas one parallel to the dorsal surface is called a *horizontal* axial section. Any axial section which is neither vertical nor horizontal is referred to as an *inclined* axial section. These terms are so employed throughout the descriptions which follow. The fact that most specimens which are found exposed on the upper surfaces of individual beds lie with the dorsal surface of the shell upward may indicate that the application of these terms to this genus is not inappropriate.

Diagnosis.—Shell minute, roughly disc-shaped, thickest near the center at the location of the coiled body of the shell and thinnest near the periphery. The maximum dimension seldom exceeds 2.5 mm. Growth of the shell may be divided into four distinct stages. The first usually consists of 1 to 1½ discoidal volutions whose axis of coiling is the shorter diameter. This stage is usually coiled at right angles to the one which follows. The second stage consists of about 2 ellipsoidal whorls whose axis of coiling is the greater diameter. Stage three consists of an uncoiled flare which extends roughly tangential to the terminal portion of the second stage. Chambers of stage three are extended laterally and their ends are sharply recurved around the poles of the coiled body of the shell to terminate against the posterior side of the second stage (Text-fig. 1A). The opposite ends of successive chambers progressively approach the sagittal plane, and one another, on the posterior side of the shell. The septa of these chambers are incurved toward the ventral surface of the body of the shell, and their distal margins are in contact with it. Each suc-



TEXT-FIG. 1—Schematic drawings of *Paradoxiella* showing mode of growth and orientation of illustrated thin sections. A, dorsal view; B, sagittal view; a-a′, b-b′, c-c′, d-d′, orientation of horizontal axial, vertical axial, inclined axial, and sagittal sections, respectively.

cessive septum is longer than the preceding one and laps across a greater portion of the ventral surface of stage two. Stage four begins when a chamber bridges the gap between the ends of the chambers on the posterior side and continues uninterruptedly around the periphery of the flare. A septum of an early chamber of stage four has the appearance of a bulging and intensely convoluted disc with an ovate orifice between the center and the posterior margin. The periphery of this orifice is the distal margin of the septum which is in contact with the ventral surface of stage two. Successive septa are progressively longer and cover a greater part of the ventral surface. Consequently, the size of the orifice progressively diminishes. Finally, a septum extends entirely across the ventral surface of the shell, and the orifice disappears. The next few septa extend uninterruptedly across the ventral surface from margin to margin, after which the septal orifice reappears and each septum has its distal margin emplaced upon the face of the preceding one. This retrogression in septal pattern may be a senile character analogous to the reduction in the height and width of the chambers of the final whorls of other fusulinids, such as *Pseudoschwagerina* and *Verbeekina*. The dorsal surface of a mature specimen is usually undulating, and the periphery is often sharply curved upward, like the brim of a hat. Some specimens are sharply bent in the middle, so that in vertical sections they appear V-shaped. The spirotheca and septa are very thin and are composed of a tectum and a diaphanotheca. The septa are intensely fluted and cuniculi are well developed. Septal pores are numerous. The tunnel is very narrow, and in the coiled portion of the shell it is bordered by weak chomata. In the flare the tunnel rises from the floor and continues as a series of openings near the upper margins of the septa. The latter display an epithecal thickening bordering this part of the tunnel.

Discussion.—Paradoxiella is so unusual in appearance that mature specimens can hardly be confused with any other described fusulinid genus. Nevertheless, sagittal sections of immature individuals which died before reaching the fourth growth stage could be confused with mature specimens of *Codonofusiella*. It seems probable that *Paradoxiella*, which is a member of the subfamily Boultoniinae, developed directly from *Codonofusiella*.

Age.—Only the type species is known at present, and it has been found exclusively in beds of uppermost Guadalupian age.

PARADOXIELLA PRATTI Skinner and Wilde, n. sp.

Plate 91, figures 7–9; plate 92, figures 1–10; plate 93, figure 1

Shell minute, virtually disc-shaped, thickened near the center of the disc and thinning toward the periphery. The coiled body of the shell commonly consists of 3 to 3½ volutions, the first 1 to 1½ of which are discoidal in shape and coiled askew to the later ones. A few specimens have as many as 5 coiled whorls with 3 belonging to the discoidal juvenarium. The later coiled volutions are ellipsoidal in shape, this portion of the shell varying from 0.28 to 0.49 mm. in length, and from 0.24 to 0.34 mm. in width. The form ratio varies from 1.05 to 1.52, averaging 1.26.

The coiled body of the shell is followed by an uncoiled flare which expands rapidly. The chambers of this flare are extended laterally, and their ends are sharply recurved about the poles to terminate against the posterior side of the coiled body of the shell. The opposite ends of each successive chamber progressively approach the sagittal plane on the posterior side of the shell. At this stage a dorsal view is bean-shaped in outline. Finally, a chamber bridges the posterior gap and extends uninterruptedly around the periphery of the flare, and all succeeding chambers follow this annular course. The difference between the number of chambers in the anterior and posterior parts of the flare, respectively, as seen in sagittal sections, represents the number of non-annular flare chambers. This number varies from 11 to 14, averaging 13. The dorsal surface of the flare is commonly undulating, and in fully grown individuals the periphery is often sharply upturned. Because of these irregularities it is difficult to obtain complete horizontal axial or tangential sections. The greatest axial

diameter of the flare which we have observed is 2.46 mm., while the greatest sagittal diameter seen is 2.88 mm. Usually these dimensions are subequal. The septa of the flare are progressively longer and are incurved against the ventral surface of the body of the shell, each septum lapping farther across that surface than the preceding one. When the chambers become annular a septum has the appearance of a bulging and intensely convoluted disc with an ovate orifice located between the center and the posterior margin. The periphery of this orifice is the distal margin of the septum which is in contact with the ventral surface of the body of the shell. Successive septa are progressively longer, covering a greater part of the ventral surface, and the septal orifice diminishes in size. Finally, a septum extends entirely across the ventral surface, and the orifice disappears. The next 2 to 6 septa follow this pattern and extend uninterruptedly across the ventral surface from margin to margin. Thereafter, the septal orifice reappears, and the distal margin of each septum is emplaced upon the face of the preceding one. This retrogression in septal pattern may be a senile character, analogous to the reduction in height and width of the chambers in the final whorls of such genera as *Pseudoschwagerina* and *Verbeekina*.

The spirotheca and septa are very thin, consisting of a tectum and a diaphanotheca. The septa are intensely fluted, the fluting being very regular in the coiled portion of the shell. Cuniculi are well developed, and septal pores are common. The septa number 8 to 9 in the first whorl, 11 to 14 in the second, and 15 to 20 in the third. The anterior part of the flare may have as many as 38 septa.

The proloculus is minute and usually spherical. Its outside diameter ranges from 37 to 59 microns, averaging 51 microns. The tunnel is low and very narrow, bordered by weak chomata in the coiled part of the shell. At the beginning of the uncoiled flare the tunnel no longer pierces the distal margins of the septa, but continues as a series of perforations which are progressively higher above the distal margins. Its distance below the tops of the septa is essentially constant and about the same as in the terminal part of the coil. The tunnel of the flare is bordered by epithecal thickening of the septa.

The following measurements apply only to the coiled portion of the shell.

TABLE OF MEASUREMENTS (IN MILLIMETERS)

Specimen	Half Length			
	0	1	3	3
A	.028	.047	.085	.173
B	.025	.038	.093	.141
C	.027	—	.102	.175
D	.027	—	.133	.243
E	.030	—	.116	.217
F	.028	.042	.092	.161
G	.020	—	—	.179
H	.023	.034	.092	.190

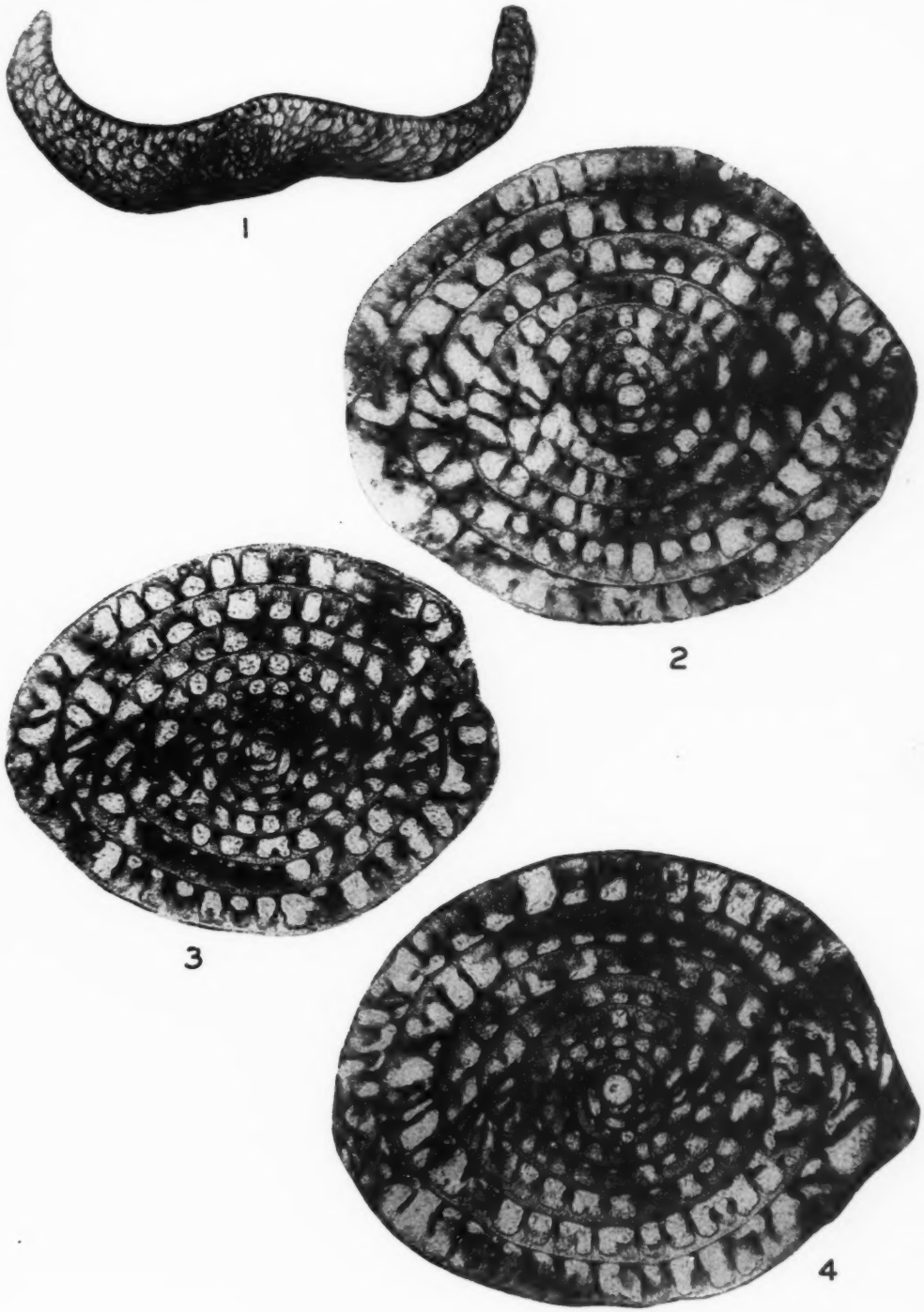
Specimen	Radius Vector			
	0	1	2	3
A	.025	.052	.083	.147
B	.025	.054	.082	.134
C	.025	—	.096	.164
D	.027	—	.096	.168
E	.025	—	.096	.169
F	.028	.063	.070	.123
G	.018	—	—	.144
H	.023	.049	.058	.125

EXPLANATION OF PLATE 93

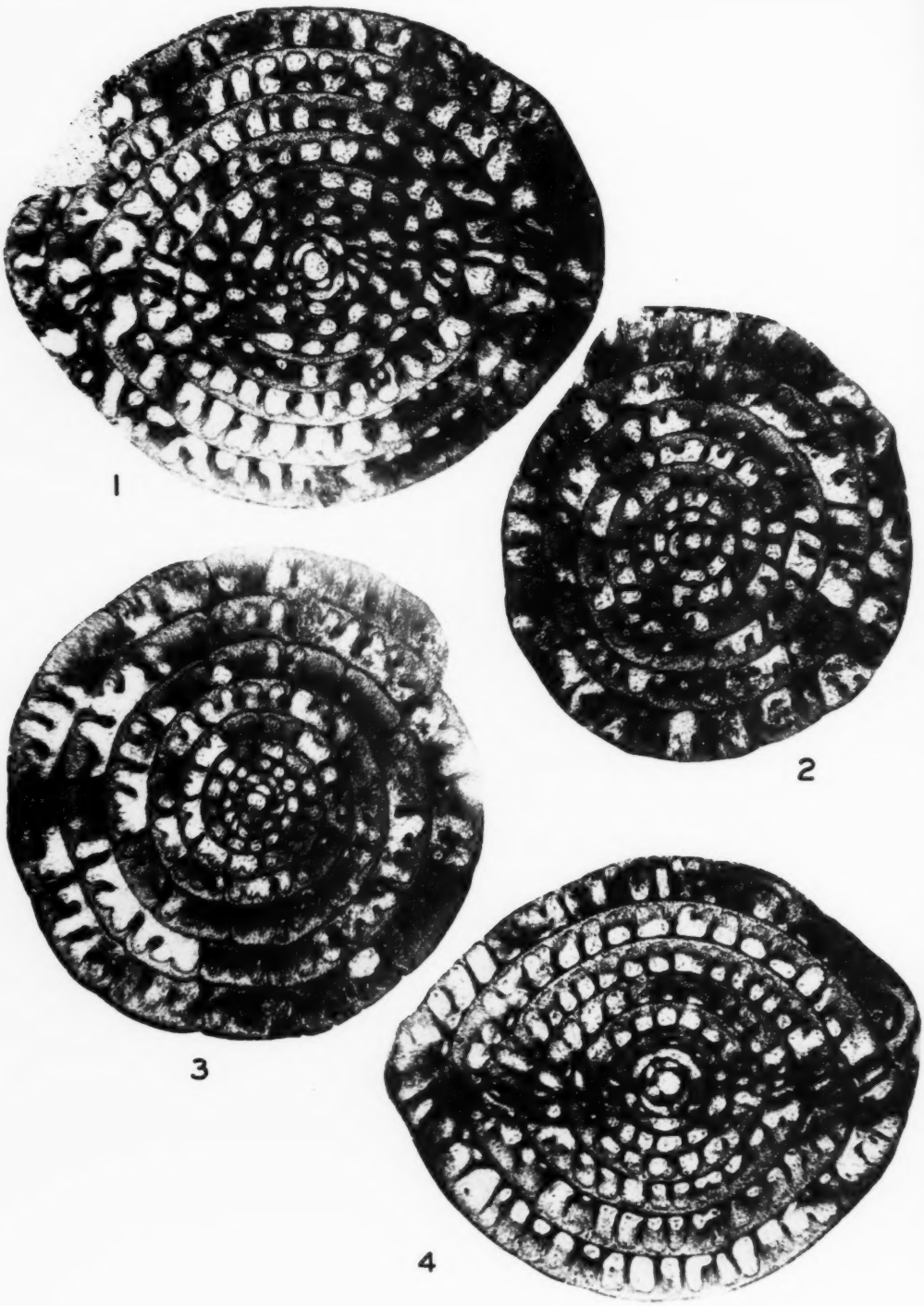
All figures are unretouched photographs.

FIG. *1*—*Paradoxiella pratti* Skinner and Wilde, n. gen., n. sp. Sagittal section of a paratype, ×30. Lamar limestone member of Bell Canyon formation, Guadalupe Mountains, Culberson County, Texas.

2–4—*Yabeina texana* Skinner and Wilde, n. sp. Axial sections of paratypes, ×40. Lamar limestone member of Bell Canyon formation, Guadalupe Mountains, Culberson County, Texas.



Skinner & Wilde, Permian fusulinids from Texas



Skinner & Wilde, Permian fusulinids from Texas

Specimen	Ratio HL/RV			
	0	1	2	3
A	1.10	0.90	1.02	1.18
B	1.00	0.70	1.13	1.05
C	1.06	—	1.06	1.07
D	1.00	—	1.39	1.45
E	1.16	—	1.21	1.28
F	1.00	0.67	1.31	1.31
G	1.05	—	—	1.24
H	1.00	0.69	1.59	1.52

Specimen	Thickness of Spirotheca			
	0	1	2	3
A	.010	.010	.014	.018
B	.007	.011	.014	.018
C	.008	.010	.011	.014
D	.010	.011	.014	.017
E	.008	.011	.014	.016
F	.008	.008	.011	.016
G	.007	.013	.014	.017
H	.007	.008	.011	.014

Specimen	Tunnel Angle		
	1	2	3
A	—	—	22
B	—	—	19
C	—	—	24
D	—	—	26
E	—	18	21
F	—	19	27
G	—	—	21

Specimen	Septal Count			
	1	2	3	4
I	—	—	16	
J	—	—	16	
K	—	12	18	
L	—	11	15	17
M	—	—	20	

Discussion.—Paradoxiella pratti, n. sp., is the only representative of this genus known at present. The appearance of mature individuals is unique, and such specimens can hardly be confused with any other described fusulinid. Sagittal sections of immature individuals, however, closely resemble species of *Codonofusiella*. The preceding description is based on a study of a large number of thin sections and of weathered specimens exposed on bedding surfaces. This remarkable species is named in honor of Mr. Wallace E. Pratt.

Occurrence.—Paradoxiella pratti is common in a zone of thin-bedded, brown, siliceous limestone extending from 15 to 30 feet above the base of the Lamar limestone member of the Bell Canyon formation. The locality is on the southwest side of a small isolated hill which lies just east of the road into McKittrick Canyon, Guadalupe Mountains, Culberson County, Texas. The hill, known locally as Buck Hill, is located about a mile north of the junction of the McKittrick Canyon road with the road leading from U. S. Highway 62 to Mr. Pratt's ranch house.

Rare specimens occur in the light-colored, cherty limestones which immediately overlie this zone and which cap Buck Hill. These limestones contain abundant specimens of *Reichelina lamarensis*, n. sp. A few specimens have also been found in the basal clastic limestone of the Lamar along the north side of McKittrick Canyon in front of the steep slope of the mountains.

Genus YABEINA Deprat, 1914

YABEINA TEXANA Skinner and Wilde, n. sp.

Plate 93, figures 2–4; plate 94, figures 1–4; plate 95, figures 1–4

Shell minute, inflated ellipsoidal, with strongly convex lateral slopes and bluntly rounded poles. Mature specimens have 8 to 10 volutions, the first two of which are sometimes coiled at an angle to the outer

EXPLANATION OF PLATE 94

All figures are unretouched photographs.

FIGS. *1–4*—*Yabeina texana* Skinner and Wilde, n. sp. *1*, axial section of the holotype, ×40; *2,3*, sagittal sections of paratypes, ×40; *4*, axial section of a paratype, ×40. Lamar limestone member of Bell Canyon formation, Guadalupe Mountains, Culberson County, Texas.

TABLE OF MEASUREMENTS (IN MILLIMETERS)

Half Length

Specimen	0	1	2	3	4	5	6	7	8	9
A	.058	.096	.142	.238	.345	.474	.617	.786	.937	1.077
B	.063	.104	.156	.252	.364	.501	.638	.756	.942	
C	.049	.077	.129	.211	.296	.408	.559	.707	.869	
D	.058	.079	.140	.216	.318	.441	.584	.792	.992	
E	.060	.090	.164	.238	.356	.488	.666	.849	—	
F	.058	.119	.192	.288	.408	.523	.669	.880	1.063	

Radius Vector

Specimen	0	1	2	3	4	5	6	7	8	9
A	.060	.090	.145	.208	.279	.364	.482	.619	.773	.923
B	.063	.107	.153	.216	.301	.406	.515	.665	.830	
C	.049	.082	.134	.189	.249	.343	.444	.573	.704	
D	.049	.090	.145	.206	.290	.397	.510	.660	.789	
E	.052	.126	.186	.263	.351	.455	.603	.756	—	
F	.060	.115	.175	.241	.337	.436	.573	.734	.891	

Ratio of HL/RV

Specimen	0	1	2	3	4	5	6	7	8	9
A	0.95	1.07	0.98	1.14	1.24	1.30	1.28	1.27	1.21	1.17
B	1.00	0.97	1.02	1.17	1.21	1.23	1.24	1.15	1.13	
C	1.00	0.94	0.96	1.12	1.19	1.19	1.26	1.23	1.23	
D	1.16	0.89	0.97	1.05	1.10	1.11	1.15	1.20	1.26	
E	1.16	0.71	0.88	0.90	1.01	1.07	1.10	1.12	—	
F	0.95	1.03	1.10	1.20	1.21	1.20	1.17	1.20	1.19	

Thickness of Spirotheca

Specimen	0	1	2	3	4	5	6	7	8	9
A	.008	.010	.014	.017	.023	.028	.025	.024	.021	.020
B	.010	.013	.013	.016	.023	.025	.021	.020	.018	
C	.010	.011	.014	.016	.018	.017	.016	.018	.018	
D	.010	.011	.014	.017	.016	.018	.016	.016	.016	
E	.010	.011	.016	.018	.020	.025	.023	.021	—	
F	.008	.011	.013	.016	.018	.020	.030	.021	—	

Parachomata Count

Specimen	1	2	3	4	5	6	7	8	9
A	—	3	4	6	8	11	15	18	20
B	2	3	5	6	9	10	15	19	
C	2	3	4	7	9	11	15	17	
D	1	3	5	8	10	12	16	17	
E	1	3	5	8	10	14	18	—	
F	2	4	7	9	11	13	16	18	

Septal Count

Specimen	1	2	3	4	5	6	7	8	9	10
G	4	4	9	9	9	11	13	13	13	17
H	—	4	12	13	12	11	13	14	—	
I	7	9	11	11	11	11	15	15	—	
J	6	8	8	9	8	11	12	13	13	—
K	4	5	7	11	12	13	16	—		
L	3	8	9	9	10	11	—			

ones. They vary from 1.8 to 2.1 mm. in length and from 1.3 to 1.8 mm. in width. The form ratio varies from 1.18 to 1.34, and averages 1.26.

The spirotheca is thin and is composed of a tectum and a finely alveolar keriotheca. All measurements of its thickness have been made near the middle of the shell and midway between two adjacent septula. In the seventh whorl the thickness varies from 16 to 24 microns, averaging 19 microns.

The septa are not folded but are somewhat irregular in the path they follow from pole to pole. They are irregularly spaced, so that the width of the chambers is quite variable within a given volution, but the general tendency is toward wider spacing in the outer volutions. The average septal count for six specimens from the first to the tenth whorls is 5, 6, 9, 10, 10, 11, 14, 14, 13, 17.

Parachomata are present throughout the shell. They are relatively low and broad in the inner whorls, but high and narrow in the outer ones. Their number averages about 15 in the seventh volution. Above each parachoma, and in contact with it, is a primary transverse septulum. These septula are pendant, ribbon-like extensions of the alveoli of the spirotheca and are essentially at right angles to the septa. They are pierced by small, rounded lateral passages which are located immediately in front of and behind the septa. None has been observed in the middle of a chamber. These openings are usually roughly circular and located a short distance above the floor of the chambers at the junction of the transverse septula and the parachomata. Occasionally, however, a much larger one is observed which extends from the floor of the chamber to well up in the septulum. In such cases the opening is elliptical in shape, being higher than wide.

Secondary transverse septula, intercalated between adjacent primary transverse septula and shorter than the latter, are present in the outer whorls. Their occurrence is sporadic and they are often discontinuous, being most strongly developed at their intersections with the septa and weakly developed or absent across the central part of the chambers. They have not been observed in the first four volutions; rarely one or two appear in the fifth; several are usually present in the sixth and seventh; and they are common from the eighth whorl outward. Only one secondary septulum has been observed between a pair of primary septula, even in the outermost volution. Through the seventh whorl the secondary transverse septula are usually short, broad, and rudimentary in appearance. From the eighth whorl outward they are usually longer (extending about half way to the floor of the chamber) and narrower, occasionally being somewhat constricted in the upper portion so that they appear slightly club-shaped in vertical section. In the outer whorls the distal margins of the septula appear compact and structureless, probably due to a plugging of the ends of the alveoli with epitheca.

Axial septula rarely appear in the second volution but commonly are first observed in the third. A second axial septulum per chamber usually makes its first appearance at about the end of the fourth whorl, and a third may appear as early as the fifth whorl but is commonly observed at about the end of the sixth. From the eighth volution outward four axial septula per chamber are common, and five are occasionally present. Because of the marked variation in the width of the chambers the number of axial septula per chamber is also highly variable, chambers with only one septulum being present even in the outer whorls. Shortly after the first appearance of a second septulum per chamber, usually in the fifth whorl, the axial septula become differentiated into two kinds. Both, like the transverse septula, are ribbon-like extensions of the alveoli of the keriotheca. One type is slender and elongate while the other is relatively short and broad. The distal margins of the elongate septula are compact and structureless, but the margins of the short ones are seldom so consolidated. There appears to be no definite pattern of alternation of the two types, although a long septulum is nearly always present immediately behind each septum in the outer whorls. In addition, no more than three of the same type have been observed in any one chamber.

The basal margins of both the septa and the elongate axial septula are pierced by rows of rounded foramina. These openings are located between each pair of adjacent parachomata. They are usually nearly circu-

lar, but occasionally they are elliptical with the greater diameter parallel to the axis of coiling.

The proloculus is small and usually spherical, its outside diameter varying from 82 to 126 microns and averaging 106 microns.

Discussion.—*Yabeina texana*, n. sp., is the smallest neoschwagerinid known and does not closely resemble any described form. In addition, it appears to be the most primitive species of the genus yet described. Geographically, the nearest congeneric species is *Yabeina packardi* Thompson and Wheeler. It was obtained from a cobble in Tertiary gravel in central Oregon. Thus, the discovery of *Yabeina* in West Texas extends the known geographic range of the genus by more than 1500 miles.

Occurrence.—This species is not rare in the basal 15 feet of the Lamar limestone near the end of a small spur on the south side of Bear Canyon, on the southeast slope of the Guadalupe Mountains, Culberson County, Texas. This locality is one-half mile slightly north of west from Wallace E. Pratt's ranch house, and about 200 yards southwest of a water well and pumping unit. We have also found it in the basal beds of the Lamar limestone in the north wall of Bear Canyon, due north of the pumping unit.

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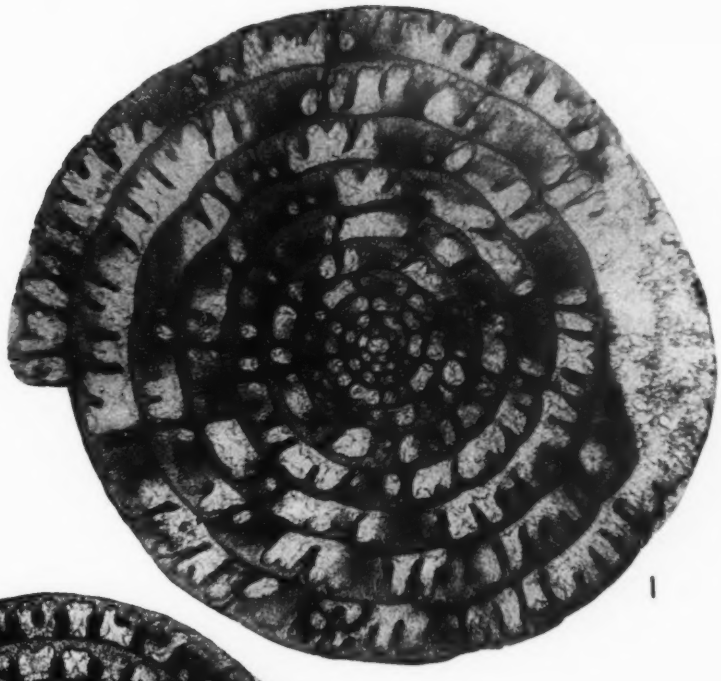
EXPLANATION OF PLATE 95

All figures are unretouched photographs.

FIGS. *1–4*—*Yabeina texana* Skinner and Wilde, n. sp. *1,4*, sagittal sections of paratypes, ×40; *2*, axial section of paratype ×40; *3*, part of specimen shown in *2*, enlarged, ×100, to show development of secondary transverse septula. Lamar limestone member of Bell Canyon formation, Guadalupe Mountains, Culberson County, Texas.



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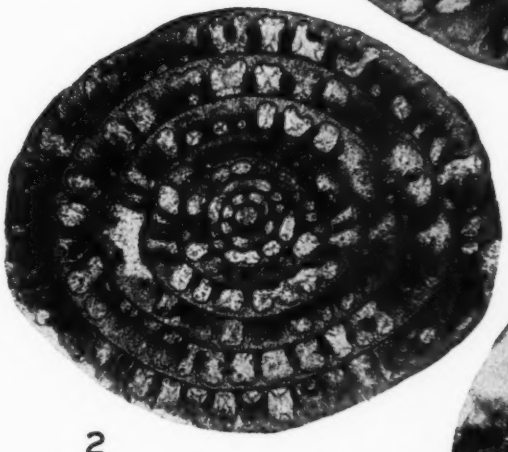

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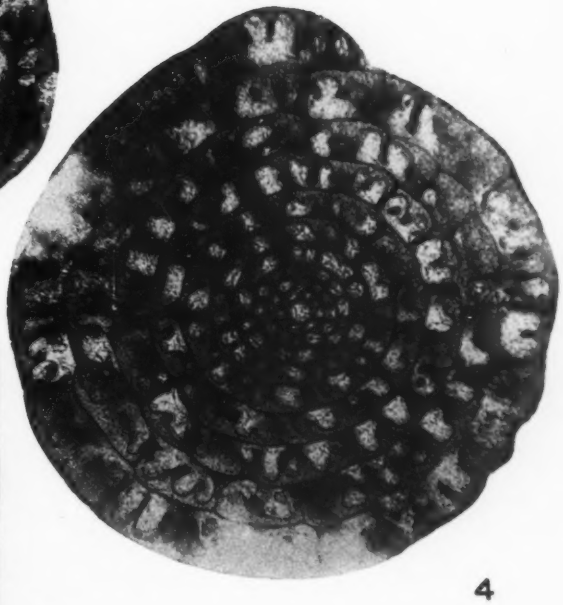

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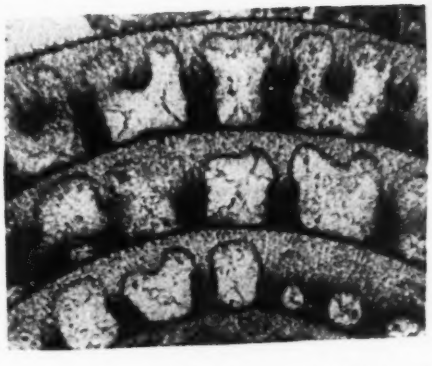
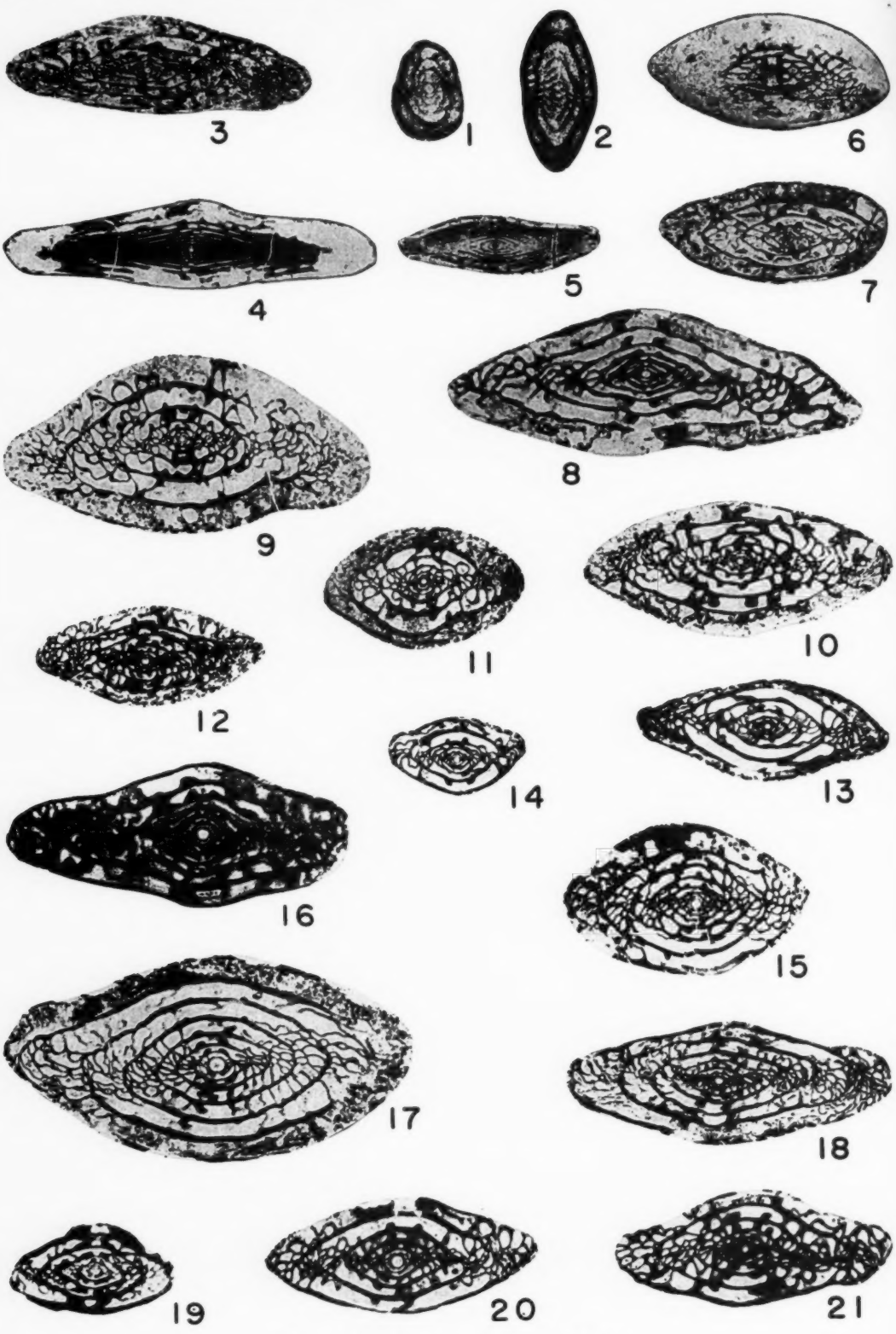


3

Skinner & Wilde, Permian fusulinids from Texas



Bostwick, Fusulinids from Idaho

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STRATIGRAPHY OF THE WOOD RIVER FORMATION, SOUTH-CENTRAL IDAHO

DAVID A. BOSTWICK
Oregon State College, Corvallis

ABSTRACT—The Wood River formation near Bellevue, Idaho, contains fusulinids that compare closely with those of Desmoinesian, Virgilian, and Wolfcampian ages in rocks of the Mid-Continent and Southwest regions of the United States. With the exception of several hundred feet of conglomerates and limestones near the base, the Wood River formation is a succession of calcareous sandstones and arenaceous limestones of 12,000 feet maximal thickness in the area described. On the basis of fusulinid faunas, correlations are suggested with other formations of western United States.

INTRODUCTION AND GENERAL REMARKS

THE Wood River formation was named by Lindgren in 1900 as a stratigraphic unit of sandstones, limestones, and shales near Hailey, Idaho. Later, the formation was restricted by Umpleby, Westgate, and Ross (1930) to the calcareous and quartzitic sandstones with smaller amounts of conglomerate, shale, and dolomitic limestone, which make up most of the rocks in the Wood River region.

Former workers have considered the Wood River formation to be of Pennsylvanian age. Fossils, including fusulinids, have been reported to occur throughout the formation and have been recognized as having Pennsylvanian affinities. *Fusulina secalica* and *Fusulina?* sp. have been included in several published faunal lists. With these exceptions, few statements have been published concerning the fusulinids of the Wood River formation. This report concerns a study of fusulinid collections obtained from three stratigraphic sections of the Wood River, measured in the vicinity of Bellevue, Idaho. My study of the fusulinid faunas indicates that the Wood River formation contains Pennsylvanian rocks of Desmoinesian and Virgilian age, and Permian rocks of Wolfcampian age. Possibly rocks of Atokan age are also present.

The field work in connection with this

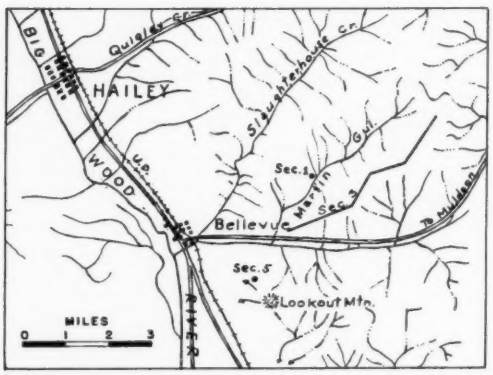
EXPLANATION OF PLATE 96

All illustrations on this plate are unretouched photographs.

FIG. *1*—*Staffella* cf. *S. powwowensis* Thompson, ×20.
2—*Nankinella* sp., ×20.
3—*Fusulinella?* sp., ×10.
4, 5—*Wedekindellina euthysepta* (Henbest), ×10.
6—*Fusulina* sp., ×10.
7—*Triticites* aff. *T. cullomensis* Dunbar & Condra, ×10.
8—*Waeringella* sp., ×20.
9—*Triticites* aff. *T. plummeri* Dunbar & Condra, ×10.
10—*Triticites* cf. *T. hobblensis* Thompson, Verville, & Bissell, ×10.
11—*Triticites* aff. *T. plummeri* Dunbar & Condra, ×10.
12—*Triticites* sp., A, ×10.
13, 14—*Triticites* aff. *T. cullomensis* Dunbar & Condra, ×10.
15—*Triticites* aff. *T. ventricosus sacramentoensis* Needham, ×10.
16—*Waeringella* sp. A. ×20.
17—*Triticites* cf. *T. ventricosus* (Meek & Hayden), ×10.
18—*Triticites* aff. *T. victorioensis* Dunbar & Skinner. ×10.
19—*Pseudofusulinella* sp. A., ×10.
20—*Triticites* cf. *T. subventricosus* Dunbar & Skinner, ×10.
21—*Triticites* cf. *T. victorioensis* Dunbar & Skinner, ×10.

study of the Wood River formation was done in July 1949. Five stratigraphic sections were measured in the general region of the Bellevue-Muldoon road, east and southeast of Bellevue (Text-fig. 1). However, fusulinid collections from only three of these sections have been studied in the preparation of this report. Fusulinids are especially abundant in exposures a few miles east of Bellevue, along the crests of ridges immediately north of the Bellevue-Muldoon road. Outcrops on the ridge tops are generally free of mantle, and weathering has revealed fusulinids at many horizons throughout the section.

Faulting is indicated at several places on the ridges east of Bellevue, but the absence



TEXT-FIG. 1—Bellevue, Idaho, and vicinity, showing locations of Sections 1, 3, and 5.

of distinct lithologic units in the formation prevented a determination of the displacements. They probably are not large enough to disturb greatly the stratigraphic succession of the fusulinid collections.

Umpleby (1917) measured and described a section of the Wood River formation along the ridge north of the Bellevue-Muldoon road a few miles east of Bellevue, and he obtained a thickness of 7,115 feet by the use of a pace traverse. I measured the Wood River to be 12,190 feet thick by tape and Brunton compass in the same general area as that measured by Umpleby, but my traverse was directed somewhat further north to avoid an area of suspected faulting. Umpleby, Westgate, and Ross (1930) considered 8,000 feet a minimum thickness of the formation in the vicinity of Hailey.

The considerable difference between Umpleby's thickness and that which I obtained is perhaps partly attributable to the more northerly traverse of my measured section, which includes a somewhat higher stratigraphic level. Because of the difficulty of obtaining reliable dips and strikes in the upper part of the formation at this locality and because of faulting of undetermined displacement, the computed thickness of 12,000 feet along this traverse must be regarded as maximal, with true thickness probably between 12,000 feet and the estimate of 8,000 feet by Umpleby, Westgate, and Ross.

Collections used in this study of the Wood River fusulinids were made from three measured sections in the vicinity of Bellevue (Text-fig. 1). Section 1 consists of several hundred feet of conglomerate, sandstone, and limestone near the base of the formation on the north side of Martin Gulch, 2.1 miles above its intersection with the Bellevue-Muldoon road. The fusulinids were collected from limestones between 30 and 50 feet above the thin upper conglomerate member.

The base of Section 3 occurs on the west slope of the spur within the acute angle formed at the intersection of Martin Gulch and the Bellevue-Muldoon road, two miles east of Bellevue. This section extends about four miles to the northeast along the crest of the divide and includes some 12,000 feet of the Wood River formation. Fusulinids occur at many horizons throughout the section.

My collection of fusulinids from Section 5 was obtained from limestones 10 to 20 feet above the basal conglomerates exposed on the northwest spur of Lookout Mountain.

I wish to express my thanks to Dr. M. L. Thompson, who suggested the problem of the Wood River stratigraphy and offered constructive criticism and encouragement during the preparation of this report.

SUMMARY OF EARLIER WORK

Lindgren (1900) gave the name Wood River formation to a thick sequence of rocks that included closely folded beds of limestone, quartzitic sandstone, and shale in the vicinity of Hailey, Idaho. He included within the Wood River formation dark slaty rocks which have since been designated

the Milligan formation, probably of Upper Mississippian age. Schuchert (in Lindgren, 1900) identified fossils collected west of Hailey, Idaho, including *Fusulina?* sp., and he favored placing the fauna in the Upper Carboniferous.

Umpleby (1917) measured a section of conglomerates, limestones, and calcareous sandstones about two miles east of Bellevue, Idaho. Fossils from this section were identified by Girty, who referred them to the Pennsylvanian on the basis of the presence of *Fusulina secalica* and other fossils which he believed to indicate a Pennsylvanian age. Umpleby tentatively placed the base of the Pennsylvanian at the base of a persistant and thick conglomerate member.

The Wood River formation was restricted by Umpleby, Westgate, and Ross (1930) to rocks composed mainly of calcareous and quartzitic sandstones, but also containing conglomerates, shales, and dolomites, that make up a large part of the rocks in the Wood River region. Minimum thickness was estimated at 8,000 feet. As thus restricted, the Wood River formation does not include the black carbonaceous argillites included by Lindgren in the lower part of the formation. The argillite was designated the Milligan formation in the same report by Umpleby, Westgate, and Ross. On the basis of identification of Wood River fossils by Girty, these authors referred the formation to the Pennsylvanian.

Hewett (in Umpleby, Westgate, & Ross, 1930) measured and described the lower 2,037 feet of the Wood River exposed on the northwest spur of Lookout Mountain about two miles southeast of Bellevue. Schuchert (in Umpleby, Westgate, & Ross, 1930) identified *Fusulina secalica* and other fossils from the lower part of Hewett's section. Ross (1934) has noted that the fossils and lithology of the Wood River resemble the Wells formation of southeast Idaho more closely than any other formation. Other authors have mentioned the Wood River formation but have relied on previous publications for descriptions of the beds and for age determinations.

LITHOLOGY

The base of the Wood River formation in the Wood River region is generally characterized by the presence of a thick conglomerate. This conglomerate is made up of angular to well-rounded chert and quartzite pebbles, averaging about an inch in diameter. Abundant interstitial sand is usually present. Where exposed along the road about two miles east of Bellevue, the conglomerate member contains larger lenses of predominately angular quartzite and chert pebbles. Small lenses of sand and sandy limestone are common throughout the conglomerate member. Many of the limestone lenses contain gastropod and brachiopod shells.

The dark limestone beds that overlie the conglomerate are ridge forming. They vary in thickness from less than an inch to as much as ten feet on weathered surfaces near the top of the unit in the Bellevue area. Ross (1934) stated that these limestones contain about 80% carbonate and 20% fine quartz grains. Many of the limestone beds of this unit near Bellevue are probably of about that composition, but the many thin interbedded sandy shales probably raise to a considerably higher figure the percentage of sand in this limestone unit.

With the exception of the conglomerate which marks the base of the formation and the prominent dark limestone which overlies the conglomerate, the Wood River formation is a monotonous succession of sandstones and sandy limestones that is not easily differentiated into lithologic units. This lack of distinctive units and the considerable faulting within the formation has caused difficulty in mining the ore bodies within the formation in the Wood River region. Examination of thin sections prepared in the course of study of the fusulinids throughout the section has revealed much recrystallization and replacement even within rocks which in the field appear unaltered. All of the fusulinid specimens examined have suffered such changes during fossilization.

Ross (1934) listed the constituents of the calcareous sandstones that make up most of the formation as angular to sub-angular quartz, with minor amounts of feldspar, muscovite, magnetite, carbonaceous material, and zircon, in a fine-grained calcareous cement.

Fossils, other than fusulinids, are not common in the Wood River. A rather large

fauna of megafossils has been reported in the formation, but most of its representatives have been obtained from the limestones near its base. Fusulinids studied in the preparation of this report were collected from immediately above the basal conglomerate to the topmost exposed part of the formation. However, I did not observe in the field fossils other than fusulinids in strata above the dark limestones near the base of the formation. Examination of fusulinid-bearing rocks in the laboratory revealed many fragments of algal material in most of the collections, along with occasional tests of foraminifers other than fusulinids and unidentified shell fragments.

The Wood River formation east of Bellevue has easterly dips of moderate to high angles. Study of the fusulinid collections made along this traverse indicates that the beds are not overturned and that the beds are progressively younger from west to east along the traverse. Faulting is indicated by brecciation and slickensides at several places on the traverse. It is certain that this has introduced some error in the calculated thickness of the formation, but whether beds have been duplicated or eliminated along this traverse could not be determined.

STRATIGRAPHY

A study of the fusulinid faunas collected from the Wood River formation near Bellevue, Idaho indicates that approximately the lower third of the formation is of Pennsylvanian age and that the remainder is Lower Permian in age. Many of the fusulinids compare more or less closely with some of those described or known from the Mid-Continent and Southwest regions of the United States. On the basis of comparisons, the fusulinid-bearing rocks of the Wood River are referred to the Desmoinesian, Virgilian, and Wolfcampian.

Very few of the fusulinid specimens are well preserved. Most have undergone crushing, abrasion, etching, or replacement to some extent before or during fossilization. Because of this poor preservation, some identifications must remain uncertain until better specimens are obtained. However, adequate fusulinid specimens in my collections are well enough preserved to establish the Pennsylvanian and Permian ages of the Wood River rocks.

Many thick units of the Wood River contain few or no fusulinids. Such unfossiliferous units may well represent all the geologic time lacking representation in the fusulinid record between lower Desmoinesian and Wolfcampian ages. No definite evidence of unconformities has been observed anywhere within the formation. It seems possible that the Wood River formation may represent almost continuous deposition from its base to its top.

No fusulinids were obtained from the basal conglomerate. *Wedekindellina euthysepta* (Henbest) and *Fusulina* sp. were collected from Section 3, 85 feet above the basal conglomerate and just below a 10 foot bed of conglomerate lithologically similar to the conglomerate below. A short distance to the southwest on Lookout Mountain no thin upper conglomerate member was observed, and the conglomerate at the base of the formation there, is overlain by sandy limestones containing *Fusulinella?* sp., *Staffella* cf. *S. powwowensis*, and *Nankinella* sp. In Section 1 in Martin Gulch, about a mile northeast of the base of Section 3, at least 50 feet of sandy limestones and interbedded conglomeratic sandstone, containing *Wedekindellina euthysepta* and *Fusulina* sp., lie above the upper of two conglomerate members.

The lower conglomerates and interbedded sandy limestones of the Wood River thicken rapidly to the north. On the Wilson Creek-Big Lost River divide the basal conglomerate is reported (Umpleby, Westgate, and Ross, 1930) to be 800 feet thick with interbedded layers of gray sandy limestone. Two or more thick beds of conglomerate separated by calcareous and quartzitic beds are also stated to occur at the head of Eagle Creek, about 24 miles north of Bellevue. The top of these thick conglomerates may be somewhat younger than the top of the uppermost conglomerate near the base of the formation in the Bellevue area, but this cannot be demonstrated at present.

The genera *Staffella* and *Nankinella* have relatively long ranges. *Staffella* is known to occur from the lower Middle Pennsylvanian through most of the Permian. *Nankinella* has approximately the same range. *Staffella*

powwowensis was first described (Thompson, 1948) from the upper part of the Green Canyon group, Powwow Canyon, Texas, where it is associated with *Nankinella* and *Profusulinella*. *Fusulinella* ranges from middle Atokan into the lower Desmoinesian. The association of *Fusulinella?*, *Staffella* cf. *S. powwowensis*, and *Nankinella* sp. indicates a low Cherokee or upper Atokan age for the basal part of the Wood River. Unfortunately, the unquestioned presence of the genus *Fusulinella* in the lower Wood River beds must await collection of better preserved material.

Wedekindellina has been reported only from rocks of Desmoinesian age. *Wedekindellina euthysepta*, collected a short distance above the basal conglomerate in Martin Gulch and also near the base of Section 3 between Martin Gulch and the Bellevue-Muldoon road, indicates a lower Desmoinesian age. Specimens of *Fusulina* sp. found associated with *Wedekindellina euthysepta* are too poorly preserved to permit a specific identification but appear not to represent an advanced form of the genus. The beds containing *Wedekindellina* and *Fusulina* are considered to belong to the zone of *Fusulina* and are correlated with the Cherokee group of the Mid-Continent region.

The lower 11,900 feet of the Oquirrh formation of the south-central Wasatch Mountains contain *Wedekindellina* and *Fusulina* and have been referred to a lower Desmoinesian age by Thompson, Verville, and Bissell (1950), and beds near the top of this sequence were correlated with the Cherokee group of the Mid-Continent region. No Wood River forms conspecific with those in this part of the Oquirrh are recognized, but it seems that the lower 305 feet of the Wood River formation in Section 3 may be correlated with part of the lower 11,900 feet of the Oquirrh.

The Quadrant formation at its type section contains *Wedekindellina* and *Fusulina* and has been stated (Thompson and Scott, 1941) to be of middle Desmoinesian age. Dunbar (in Love, 1939) identified *Wedekindellina* from the upper part of the Quadrant 20 miles west of the type section and considered it to be of Cherokee age. The Quadrant is considered to be of approximately the same age as that part of the Wood River formation that contains *Wedekindellina* and *Fusulina*.

Thompson (1945) described *Wedekindellina matura* and *W. henbesti* from the Youghall formation in the eastern Uinta Mountains and correlated the Youghall with part of the Cherokee group of Iowa and Kansas. Roth and Skinner (1930) described two species of *Wedekindellina* and two forms of *Fusulina* from the upper McCoy formation of Colorado. Forms in the Wood River, although not recognized to be conspecific with those of the Youghall and McCoy, indicate that the lower Wood River beds may be correlated with part of the Youghall and the upper part of the McCoy.

Thompson (1936) described forms of *Fusulinella*, *Fusulina*, and *Wedekindellina* from the Hartville formation near Guernsey, Wyoming and correlated the beds containing *Wedekindellina* and *Fusulina* with beds of the mid-part of the Cherokee group of Iowa. This part of the Hartville is therefore of about the same age as beds carrying *Wedekindellina* and *Fusulina* in the lower part of the Wood River formation. If the forms in my collections from Lookout Mountain that are tentatively identified as *Fusulinella?* sp. prove to belong to that genus, rocks at this horizon of the Wood River formation may possibly be correlated with a part of the lower 150 feet of the Minnelusa formation near Loring Siding, South Dakota, and beds in the lower part of the Hartville formation at Guernsey, Wyoming.

Branson (1939) identified *Fusulina* and *Staffella* from the middle part of the Tensleep formation seven miles south of Thermopolis, Wyoming, indicating a middle Desmoinesian age (Thompson and Scott, 1941), and that this horizon is about the same age as beds in the Wood River formation that contain *Fusulina* and *Wedekindellina*.

Williams (1943) stated that the Weber quartzite of the Uinta Mountains, Utah, may be of Desmoinesian age, although the upper parts of thicker sections may be younger. Red beds beneath the Weber quartzite in Weber Canyon have been called the Morgan formation. Williams (1943) reported *Fusulinella* sp. near the top and referred the Morgan to the Des-

moinesian. Although forms referred to *Fusulinella* are known in Desmoinesian rocks, the presence of *Fusulinella* without *Fusulina* suggests that the Morgan formation is upper Atokan in age. The *Wedekindellina* and *Fusulina* zone of the Wood River formation is probably of about the same age as part of the Weber quartzite. If *Fusulinella* is present at the top of the basal conglomerate on Lookout Mountain, the basal beds of the Wood River probably do not differ greatly in age from the Morgan.

Collections from the Bellevue area contain no fusulinids that demonstrate the presence of upper Desmoinesian or Missourian rocks. Forms of *Triticites* that indicate a Virgilian age were collected about 1,300 feet above the base of the formation. Beds containing *Wedekindellina* and *Fusulina* are overlain by 110 feet of nearly black fossiliferous limestone in which no fusulinids were found. This limestone, together with approximately 1,000 feet of non-fossiliferous calcareous sandstone and sandy limestone which make up the remainder of the section below the lowest collection of *Triticites*, possibly represent a part or all of upper Desmoinesian and Missourian time.

Forms of *Triticites* of Virgilian age occur in rocks 1,300 feet to 4,850 feet above the base of the Wood River formation. Several forms studied from this interval seem to be new. The remaining forms compare favorably with some described previously from Virgilian rocks in the Mid-Continent and Rocky Mountain regions. These latter forms may not prove to be conspecific with previously described forms.

Forms I am referring to *Triticites* aff. *T. cullomensis*, *Triticites* cf. *T. hobblenis*, and *Waeringella* sp. occur at several horizons in the interval 1,300 feet to 4,850 feet above the base of the formation. *Triticites cullomensis* Dunbar and Skinner, 1927, was first described from the Beil limestone of Kansas of middle Shawnee age. *Triticites hobblensis* Thompson, Verville, and Bissell, 1950, was described from the upper Pennsylvanian part of the Oquirrh formation and correlated with the Shawnee group of the Mid-Continent region. Only two species of *Waeringella* have been described. *Waeringella spiveyi* Thompson, 1942, was described from the Salem School limestone of Texas. *Waeringella bailkeyi* Thompson, Verville, and Bissell, 1950, was described from rocks of Shawnee age in the Oquirrh formation. Some specimens of *Waeringella* in the Wood River are closely similar to *W. bailkeyi*.

I am referring one form found near the top of the Pennsylvanian Wood River rocks to *Triticites* aff. *T. plummeri*. *Triticites plummeri* Dunbar and Condra, 1927, is upper Shawnee in age. However the Wood River form possesses some features that suggest a Wabaunsee age. Since it occurs at a horizon stratigraphically below forms referred to *Triticites* cf. *T. hobblensis* and *T.* aff. *T. cullomensis*, it is considered to be of Shawnee age, possibly upper Shawnee.

Thompson, Verville, and Bissell, (1950) have reported *Triticites cullomensis* from the upper 1,200 feet of Pennsylvanian rocks in the Oquirrh formation and correlated these beds with the Shawnee. The Wood River rocks that contain *Triticites* cf. *T. cullomensis*, *T.* cf. *T. hobblensis*, and *Waeringella* sp. are of approximately the same age as the upper 1,200 feet of the Pennsylvanian part of the Oquirrh.

Thompson (1936) assigned the upper Hartville formation of Wyoming to the upper Missourian or lower Virgilian. Fusulinids of Virgilian age in the Wood River seem to be somewhat younger than those of the upper Hartville, but some part of the unfossiliferous rocks lower in the Wood River section may be of the same age as the upper Hartville. *Triticites cullomensis*, *T. "exiguus,"* and *T. pygmaeus* reported by Condra, Reed, and Sherer (1940) from the Hartville were not illustrated and cannot be compared with the Wood River forms. The presence of *Triticites cullomensis* in the Hartville would indicate a probable close correlation of the upper Hartville and part of the Wood River formation.

Rocks of Wabaunsee age are perhaps present in the Wood River, but insufficient evidence at hand prevents a definite correlation at the present time. Several Wood River forms of *Triticites* seemingly have close affinities with *T. ventricosus sacramentoensis* Needham, 1937, described from the Fresnal group of New Mexico. No significant lithologic break between the Pennsylvanian and Pernian beds was observed. If none exists,

it seems reasonable to assume that some Wabaunsee rocks are present in the Wood River.

So far as known, no one has previously indicated that the Wood River formation is even in part Permian in age. The break between the two systems is placed in this report at the base of the lowest lithologic unit that contains fusulinids which compare closely with fusulinids of Lower Permian (Wolfcampian) age of other American areas. No species of fusulinid in the Wood River formation is known to cross this boundary. Fusulinids identified as *Triticites* cf. *T. ventricosus* occur in rocks 4,850 feet above the base of the formation. This form compares closely with *Triticites ventricosus* (Meek and Hayden), 1858, from the Hughes Creek shale and equivalent lower Wolfcampian rocks of the Mid-Continent region. *Triticites cellamagnus* Thompson and Bissell, 1954, occurs 1,600 feet above the Pennsylvanian-Permian boundary and 6,470 feet above the base of the Wood River formation. *Triticites cellamagnus* was described from the Wolfcampian part of the Oquirrh formation of Utah. Other representatives of *Triticites* from the Permian part of the Wood River resemble previously described forms from Permian rocks, but several seem to be new species.

Pseudofusulinella is abundantly represented in upper Wood River rocks. The genus has been described from exposures near Kamloops, B. C., the McCloud limestone of California, and the upper Oquirrh of Utah, all of Permian age. The range of the genus does not appear to be certain at this time. One Wood River form is here identified with *P. utahensis* Thompson and Bissell, originally from the upper Oquirrh.

Fusulinids referred to the genus *Schwagerina* were collected from rocks 1,860 feet above the systemic break and at several higher horizons. Although the presence of the genus can be established in the upper Wood River formation, the poor preservation of most of the specimens of *Schwagerina* in my collections makes specific identification difficult and uncertain. The Wood River forms of *Schwagerina* do not seem far advanced and probably are not younger than lower Wolfcampian.

Specimens of a form identified as *Rugosofusulina* sp. were collected from horizons 1,965 feet and 2,655 feet above the systemic break. *Rugosofusulina* is widely distributed in rocks of Wolfcampian age (Thompson, 1948).

Few fusulinids of Wolfcampian age have been described from the central and northern Rocky Mountains. Miller and Thomas (1936) described a form from the upper part of the Casper formation, in Albany County, Wyoming, which they referred to *Triticites ventricosus* (Meek)?. This form seems to be closely related to *T. pinguis* Dunbar and Skinner described from the Wolfcamp formation and to *T. cellamagnus* Thompson and Bissell described from the Oquirrh. It also closely resembles the Wood River form which I have referred to *Triticites cellamagnus*. Probably the upper part of the Casper formation in the above mentioned area is of about the same age (lower Wolfcampian) as the Permian part of the wood River.

Bissell (1939) and Baker and Williams (1940) reported *Schwagerina* and *Pseudoschwagerina* from the upper Oquirrh. Thompson and Bissell (in Thompson, 1954) list *Schwagerina*, *Pseudoschwagerina*, and *Pseudofusulina* from the upper Oquirrh. Because of the poor preservation of many of the Wood River fusulinids I am unable to identify the *Schwagerina* species. However the Wood River representatives of *Schwagerina* are of about the same development and seem not to differ greatly in age from the Oquirrh forms of the genus.

Frenzel and Mundorf (1942) described forms of *Schwagerina* and *Pseudoschwagerina* from cherts near the base of the Phosphoria? formation near Three Forks, Montana, and they correlated the beds there with the Wolfcamp and Hueco formations of Texas. These forms appear to be younger than any forms in the upper Wood River.

PALEOGEOGRAPHY

The fusulinid faunal sequence in the Wood River rocks firmly establishes the presence of seas over part of central Idaho during Desmoinesian, Virgilian, and lower Wolfcampian time, with a strong probability that Missourian seas were also present. All evidence of the faunas points to sea connections with Utah, Wyoming, Montana,

and Colorado during Desmoinesian time. Virgilian and Wolfcampian faunas of the Wood River are closely similar to fusulinids of Utah, New Mexico, and Texas, supporting the conclusion that a more or less unrestricted marine trough extended from Texas and New Mexico as far north as the Wood River area of central Idaho. There appears to be evidence in the faunas that this sea was not withdrawn from this area from Desmoinesian to lower Wolfcampian.

The thick basal congomerates suggest that this sedimentary trough was not well developed in the area of present Wood River outcrops before lower Desmoinesian time. The axis of the trough probably lay somewhat to the west of the present area of outcrop, in the area now occupied by the Idaho batholith and its outliers, with Wood River deposition in a position marginal to the trough until the end of Desmoinesian time. It may be significant that the Milligan formation immediately below the Wood River contains much carbonaceous material and plant remains and is almost certainly of shallow water deposition.

Source of the clastics in the Wood River rocks is not known. The basal conglomerates denote a near-by source area of some relief. The thickening of the conglomerates toward the north may reflect a northern source, but a source to the east or northeast would account for such features of the beds as have been observed. The relationship of the Hyndman Peak area of quartzites and hornfels to the Wood River detritals should be investigated as a possible source area. The Wood River rocks flank and partly enclose this Pre-Cambrian sequence in the present area of outcrops.

The great quantity of sand in all but the lower few hundred feet of beds presents a greater problem; this appears to be closely connected with the problem of the source of the sands of the Quadrant, Oquirrh, Tensleep, and Wells formations. Petrographic examination of collections from Section 3 reveals a preponderance of quartz sand and interstitial calcite, and always less than 5% feldspars. Most thin sections in my collections show no feldspars. This seems to indicate that the Wood River sediments were derived from the stable platform to the east and represent deposition in the miogeosynclinal belt.

WOOD RIVER FUSULINID COLLECTIONS

The collections from the Wood River formation used in this report are all from a sequence of beds, beginning with the older, about two miles east of Bellevue, Idaho. Most of the collections were from a traverse that followed the divide between Martin Gulch and the unnamed valley containing the Bellevue-Muldoon road and that ended where the formation passed beneath Tertiary lavas (Text-fig. 1). Collections were also made on the northwest spur of Lookout Mountain (Collection Ida-5-2) and on the north side of Martin Gulch 2.1 miles above

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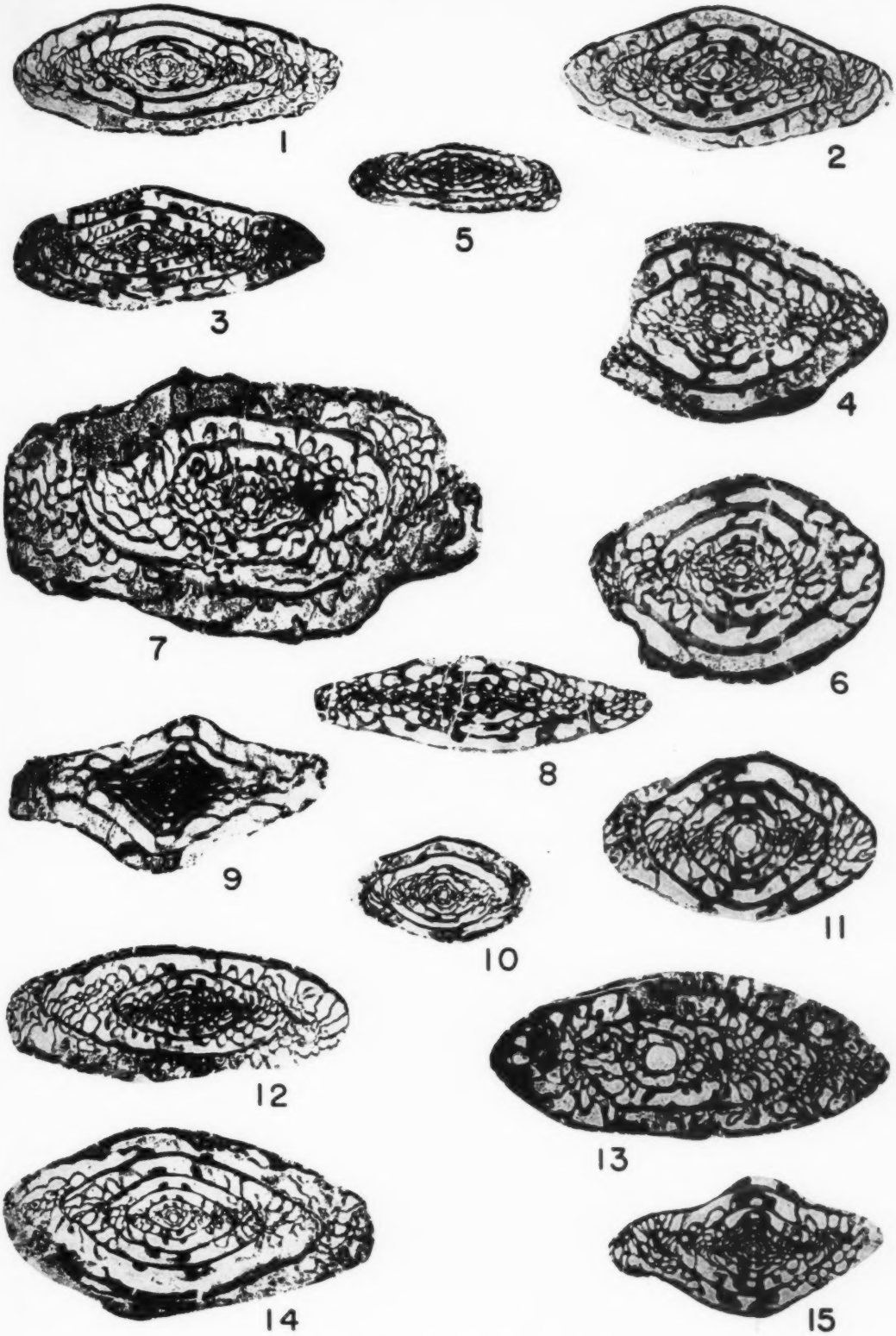
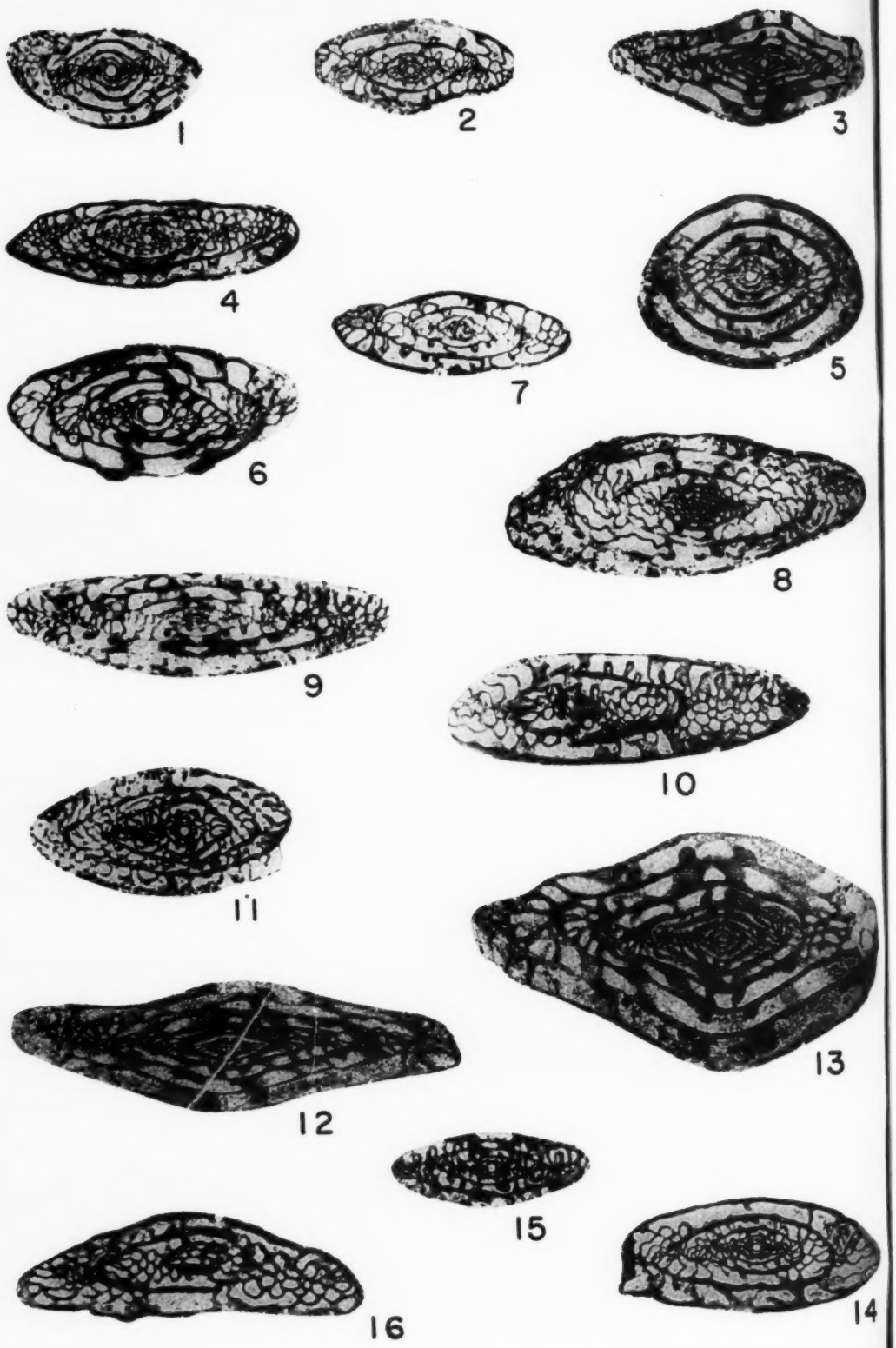
EXPLANATION OF PLATE 97

All illustrations on this plate are unretouched photographs.

FIG. *1*—*Triticites* cf. *T. meeki* (Moller), ×10.
2—*Triticites* sp. B, ×10.
3—*Triticites* sp. C, ×10.
4—*Triticites cellamagnus* Thompson & Bissell, ×10.
5—*Triticites* sp. D, ×10.
6—*Triticites* cf. *T. cellamagnus* Thompson & Bissell, ×10.
7—*Rugosofusulina* sp., ×10.
8—*Triticites* aff. *T. victorioensis* Dunbar & Skinner, ×10.
9—*Pseudofusulinella* sp. B, ×10.
10—*Triticites* sp., ×10.
11—*Triticites* cf. *T. cellamagnus* Thompson & Bissell, ×10.
12—*Triticites* aff. *T. victorioensis* Dunbar & Skinner, ×10.
12—*Rugosofusulina* sp., ×10.
14—*Triticites* aff. *T. ventricosus* (Meek & Hayden), ×10.
15—*Dunbarinella* sp. A, ×10.



Bostwick, Fusulinids from Idaho



Bostwick, Fusulinids from Idaho

its intersection with the Bellevue-Muldoon road (Collection Ida-1-2).

Ida-5-2 About 20 feet above basal conglomerate of the Wood River formation in thin-bedded limestone, on the northwest spur of Lookout Mountain. *Staffela* cf. *S. powwowensis* Thompson, plate 96, figure 1; *Nankinella* sp., plate 96, figure 2; *Fusulinella?* sp., plate 96, figure 3.

Ida-1-2 In sandy limestone about 95 feet above basal conglomerate on the north side of Martin Gulch 2.1 miles above its mouth. *Wedekindellina euthysepta* (Henbest), plate 96, figure 4; *Fusulina* sp., plate 96, figure 6.

Ida-3-5 From thin-bedded limestone 85 feet above the basal conglomerate of Section 3, two miles east of Bellevue. *Wedekindellina euthysepta* (Henbest), plate 96, figure 5; *Staffella* sp., not figured.

Ida-3-6 From dark, relatively pure limestone, 320 feet above the formation base in Section 3. *Eoschubertella?* sp., not figured.

Ida-3-19 From sandy limestone in Section 3, about 1,350 feet from the base of the formation. *Triticites* sp., not figured.

Ida-3-22 In sandy limestone 2,265 feet from the base of the formation in Section 3. *Triticites* aff. *T. cullomensis* Dunbar and Condra, plate 96, figure 7.

Ida-3-24 From sandy gray limestone, 2,680 feet from the formation base. *Waeringella* sp., plate 96, figure 8.

Ida-3-27 From sandy gray limestone, 2,940 feet above the base of the Wood River formation, Section 3. *Triticites* aff. *T. plummeri* Dunbar and Condra, plate 96, figure 9; *Triticites* cf. *T. hobblensis* Thompson, Verville, and Bissell, plate 96, figure 10.

Ida-3-30 From sandy limestone, 3,060 feet from the base of the Wood River. *Triticites* aff. *T. plummeri*, plate 96, figure 11; *Triticites* sp. A, plate 96, figure 12.

Ida-3-31 From sandy limestone, 3,370 feet above the formation's base in Section 3. *Triticites* aff. *T. cullomensis*, plate 96, figure 13.

Ida-3-32 From sandy limestone, 3,500 feet above the base. *Triticites* aff. *T. cullomensis*, plate 96, figure 14.

Ida-3-33 From sandy limestone, 3,535 feet above the base of the formation. *Triticites* aff. *T. ventricosus sacramentoensis* Needham, plate 96, figure 15; *Waeringella* sp. A, plate 96, figure 16.

Ida-3-43 From gray sandy limestone, 4,930 feet above the base of the Wood River. *Triticites* cf. *T. ventricosus* (Meek and Hayden), plate 96, figure 17; *Triticites* aff. *T. victorioensis* Dunbar and Skinner, plate 96, figure 18.

Ida-3-47 From light bluish gray sandy limestone, 5,200 feet above the formation base. *Pseudofusulinella* sp. A, plate 96, figure 19.

Ida-3-49 From light bluish gray sandy limestone, 5,205 feet above the base in Section 3. *Triticites* cf. *T. subventricosus* Dunbar and Skinner, plate 96, figure 20; *Triticites* cf. *T. victorioensis*, plate 96, figure 21.

Ida-3-53 From gray sandy limestone, 5,225 feet above the base of the formation in Section 3. *Triticites* cf. *T. meeki* (Möller), plate 97, figure 1; *Triticites* sp. B, plate 97, figure 2.

Ida-3-57 From thin-bedded gray limestone, 5,700 feet above the base of the formation in Section 3. *Triticites* sp. C, plate 97, figure 3.

Ida-3-58 From gray calcareous sandstone, 6,470

EXPLANATION OF PLATE 98

All illustrations on this plate are unretouched photographs.

FIG. *1*—*Triticites* sp., ×10.
2—*Schwagerina* sp., ×10.
3—*Pseudofusulinella* sp., ×10.
4—*Schwagerina?* sp., ×10.
5—*Triticites* cf. *T. cellamagnus* Thompson & Bissell, ×10.
6—*Triticites* sp., ×10.
7—*Schwagerina* sp., ×10.
8—*Triticites* aff. *T. victorioensis* Dunbar & Skinner, ×10.
9—*Triticites?* sp., ×10.
10—*Schwagerina* sp., ×10.
11—*Triticites?* sp., ×10.
12—*Pseudofusulinella?* sp., ×20.
13—*Pseudofusulinella utahensis* Thompson & Bissell, ×20.
14—*Schwagerina?* sp., ×10.
15, 16—*Schwagerina* spp., ×10.

feet above the base of the Wood River. *Triticites cellamagnus* Thompson and Bissell, plate, 97 figure 4; *Triticites* sp. D, plate 97, figure 5.

Ida-3-59 From gray sandy limestone, 6,820 feet above the formation base. *Triticites* cf. *T. cellamagnus*, plate 97, figure 6; *Triticites* aff. *T. victorioensis*, plate 97, figure 8; *Rugosofusulina* sp., plate 97, figure 7.

Ida-3-60 From dark sandy limestone, 7,510 feet above the base of the Wood River. *Pseudofusulinella* sp. B, plate 97, figure 9; *Triticites* sp., plate 97, figure 10.

Ida-3-61 From dark gray sandy limestone, 7,515 feet above the base in Section 3. *Triticites* cf. *T. cellamagnus*, plate 97, figure 11; *Triticites* aff. *T. victorioensis*, plate 97, figure 12; *Triticites* aff. *T. ventricosus*, plate 97; figure 14; *Dunbarinella* sp. A, plate 97, figure 15; *Rugosofusulina* sp., plate 97, figure 13.

Ida-3-63 From calcareous sandstone, about 7,710 feet from the base. *Triticites* sp., plate 98, figure 1; *Schwagerina* sp., plate 98, figure 2.

Ida-3-64 About 7,990 feet above the base of the formation in calcareous sandstone. *Pseudofusulinella* sp., plate 98, figure 3; *Schwagerina?* sp., plate 98, figure 4.

Ida-3-65 From calcareous sandstone, 8,320 feet above the base of the formation in Section 3. *Triticites* cf. *T. cellamagnus*, plate 98, figure 5.

Ida-3-66 From calcareous sandstone, 9,290 feet above the base. *Triticites* sp., plate 98, figure 6; *Schwagerina* sp., plate 98, figure 7.

Ida-3-67 About 11,060 feet above the base of the formation, in gray sandy limestone. *Triticites* aff. *T. victorioensis*, plate 98, figure 8; *Triticites?* sp., plate 98, figure 9.

Ida-3-68 From gray limestone, about 11,080 feet above the base of the formation. *Schwagerina* sp., plate 98, figure 10.

Ida-3-69 About 11,440 feet above the base in sandy limestone. *Triticites?* sp., plate 98, figure 11.

Ida-3-70 From dark sandy limestone, about 11,700 feet above the base of the formation in Section 3. *Pseudofusulinella?* sp., plate 98, figure 12; *Pseudofusulinella utahensis* Thompson and Bissell, plate 98, figure 13; *Schwagerina?* sp., plate 98, figure 14; *Schwagerina* spp., plate 98, figures 15, 16.

Respository.—All specimens illustrated have been deposited in the museum of the University of Kansas, Lawrence, Kansas.

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ECOLOGY OF LIVING BENTHONIC FORAMINIFERA, TODOS SANTOS BAY, BAJA CALIFORNIA[1]

WILLIAM R. WALTON[2]
Scripps Institution of Oceanography, La Jolla, California

ABSTRACT—Two hundred and fifteen sediment samples were collected in Todos Santos Bay, Mexico, and vicinity during eight cruises on February 5, March 3, April 24, June 4, July 16, August 28, October 9, and November 10, 1952. Thirty-three sediment samples were collected in the Estero de Punta Banda. Bathythermograms from 429 stations, salinity measurements from selected stations, and water and sediment temperature observations aid in defining the physical and chemical environments.

Living benthonic foraminiferal populations have been analyzed from 215 sediment samples, dead populations have been analyzed from 110 samples, and sediment size analyses have been made on 70 samples.

The characteristics of the sediments indicate that "relict" sediments which represent a previous environment are present in the bay along with the modern sediments representing the present environment. The occurrence of non-living shallow-water species in areas of "relict" sediments suggests that the associated foraminiferal faunas are relict, at least in part.

Four geographic assemblages (Outer Bay, Middle Bay, Inner Bay, and Marginal Bay facies) and four depth facies (less than 30 fathoms, 30–50 fathoms, 50–100 fathoms, and deeper than 350–400 fathoms) have been recognized from the distributions and abundances of the living benthonic Foraminifera. These facies suggest that variations in sediment type, food or feeding habits, etc., may limit the distribution of benthonic Foraminifera, in addition to depth and/or temperature variations.

Maximum abundances of living benthonic Foraminifera have been found to occur during the late spring and summer months and apparently are associated with spring and summer flowering of phytoplankton and the seasonal temperature maximum during August. The maximum abundance occurs between 20 and 50 fathoms, and production estimates suggest that these depths apparently are 6 times as productive as depths between 350 and 400 fathoms.

Dead-population counts are valid in defining the composition and general distribution of benthonic foraminiferal faunas but are not indicative of the actual distributions or abundances of living faunas. The rate of accumulation of detrital sediments appears to be the most important single factor in determining the magnitude of dead populations. Living-to-dead ratios of benthonic Foraminifera appear to be good indices of relative rates of sedimentation.

The occurrence of middle Tertiary strata outcropping near the surface of the sediment on the continental shelf off Todos Santos Bay suggests that some of the nonliving deeper-water species occurring in surface sediments are reworked and do not represent the living foraminiferal faunas.

INTRODUCTION

THIS study was undertaken to investigate the distribution of living Foraminifera in Todos Santos Bay, Mexico, and their relationships to the environments in which they live. Sediment samples were collected during February, 1952, covering the entire Todos Santos Bay. Additional samples were collected along a single profile from shallow water to a depth of 600 fathoms to study seasonal variation at approximately six-week intervals for the remainder of the year. The purposes are: (1) to compare the living benthonic populations with the dead populations in various environments; (2) to compare the living and dead populations with the sediment type; (3) to attempt to relate the distribution of the living faunas with known physical and chemical factors; and (4) to investigate the rate of production and accumulation of foraminiferal tests.

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[2] Now employed by Gulf Research & Development Company, Houston, Texas.

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DESCRIPTION OF THE AREA

GEOGRAPHY

Todos Santos Bay lies about 60 nautical miles southeast of San Diego on the coast of Baja California, Mexico; it extends from Lat. 31°40′ N. to 31°56′ N., and from Long. 116°36′ W. to 116°50′ W. It is a large, open bay (Text-fig. 1) with a total area of approximately 90 square miles. The bay is bounded on the south and west by the rocky, mountainous Punta Banda and the Todos Santos Islands, and on the north by the mainland coast of Baja California. The inner boundary of the bay is low and is characterized by long sandy beaches and low beach dunes.

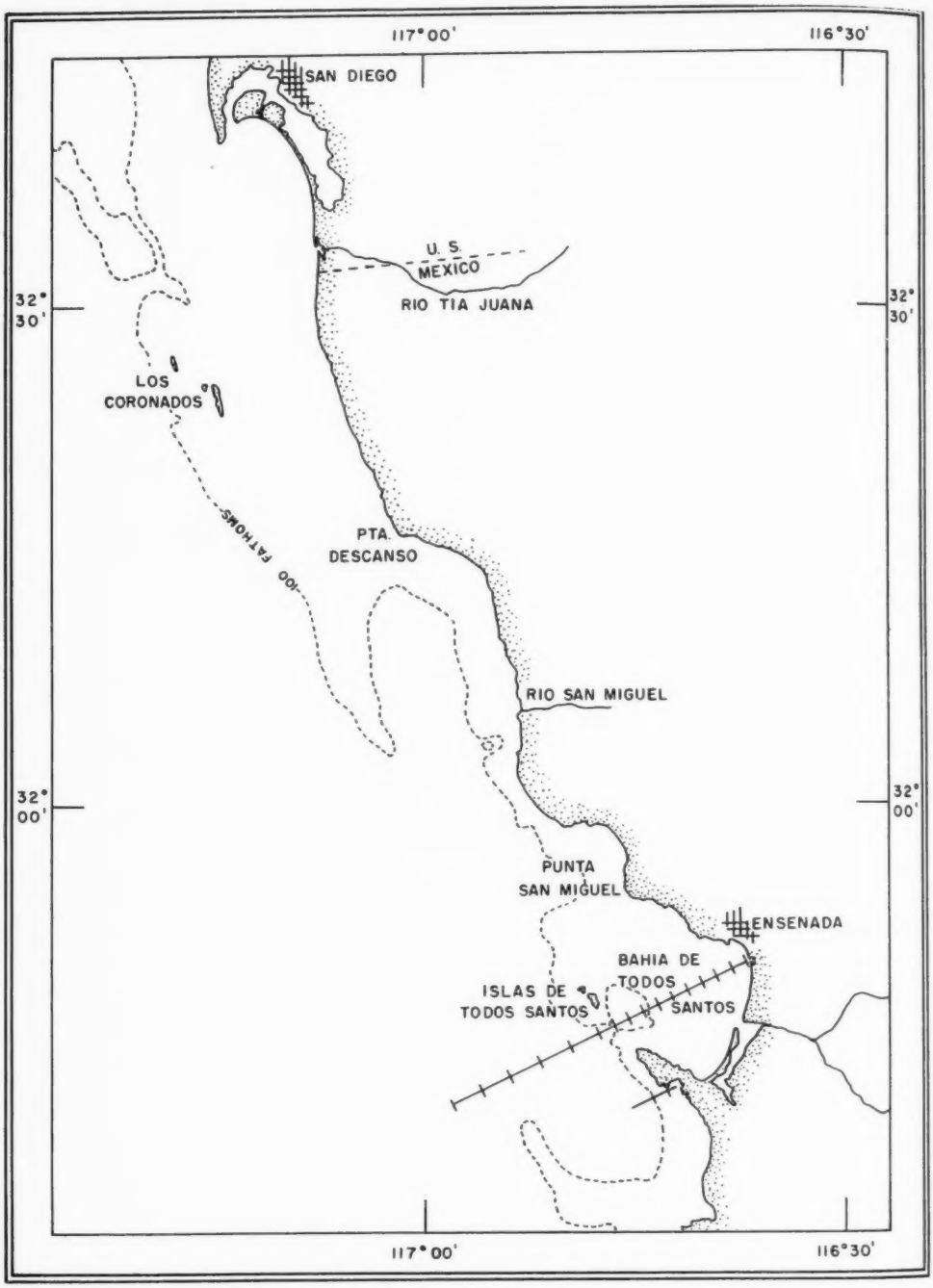
A large marine marsh, Estero de Punta Banda, is separated from the bay by a low sand spit which extends from Punta Banda toward the northeast for a distance of approximately 4 miles. It is characterized by its L-shaped main channel and poorly-developed marsh on the back side of the sand spit (Text-fig. 2). The channel is relatively shallow, not exceeding a depth of 20 feet in the deepest portion. The marsh on the west side of the Estero de Punta Banda is covered by marsh grasses. However, there is no thick accumulation of peat, and the marsh is cut along its length by sinuous tidal channels. There is no continuous fresh-water drainage into the channels, but during times of heavy rains considerable fresh water flows in through the normally dry river beds near the mouth of the estero and along the base of Punta Banda.

The south shore of Todos Santos Bay, along Punta Banda, is rocky and precipitous. The north shore of the bay also is rugged with the exception of isolated pocket beaches. The two Todos Santos Islands lie about 3.5 nautical miles northwest of Punta Banda. The south island, which is the larger, is approximately 2.5 miles long and 1.5 miles wide at the widest point. It is high (with the highest peak at approximately 300 ft. elevation), has rocky cliffs, and is inaccessible except for a few pocket beaches on the lee side. The north island is separated from the south island by a narrow, shallow channel. The north island is low and flat, and is approximately $1\frac{1}{4}$ miles long and $\frac{1}{2}$ mile wide.

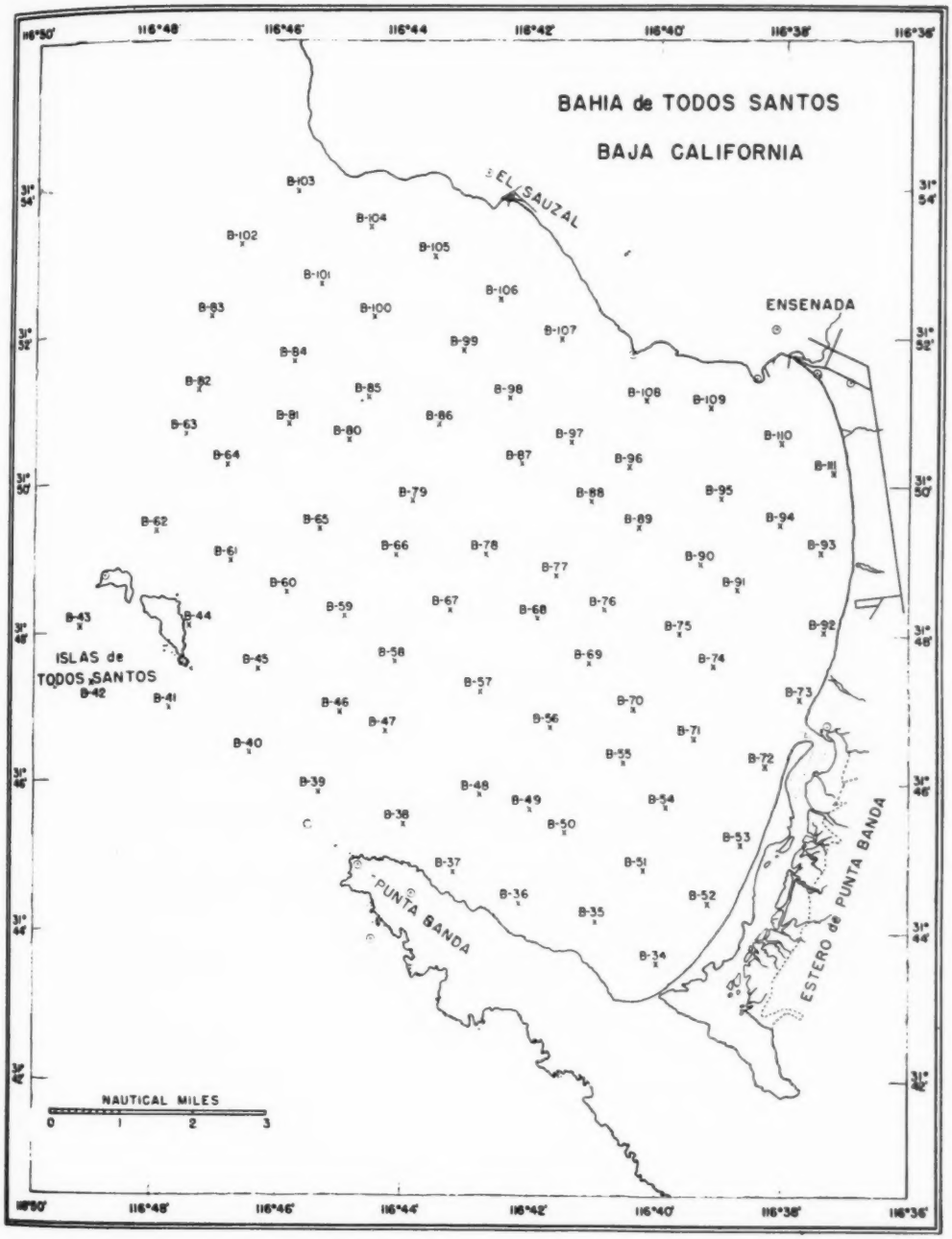
SUBMARINE TOPOGRAPHY

The water depths over most of the bay are less than 40 fathoms (Text-fig. 3). Exceptions are the deep channel between Punta Banda and the Todos Santos Islands (which is 215 fathoms deep) and the depression inside the line between the islands and Punta Banda (which is 150 fathoms deep). This depression has a moderately steep slope on the bay side but is bounded by slopes up to 30° on the side near the islands and Punta Banda. The channel is steep-sided and narrow, being only a few hundred yards wide at its deepest portion.

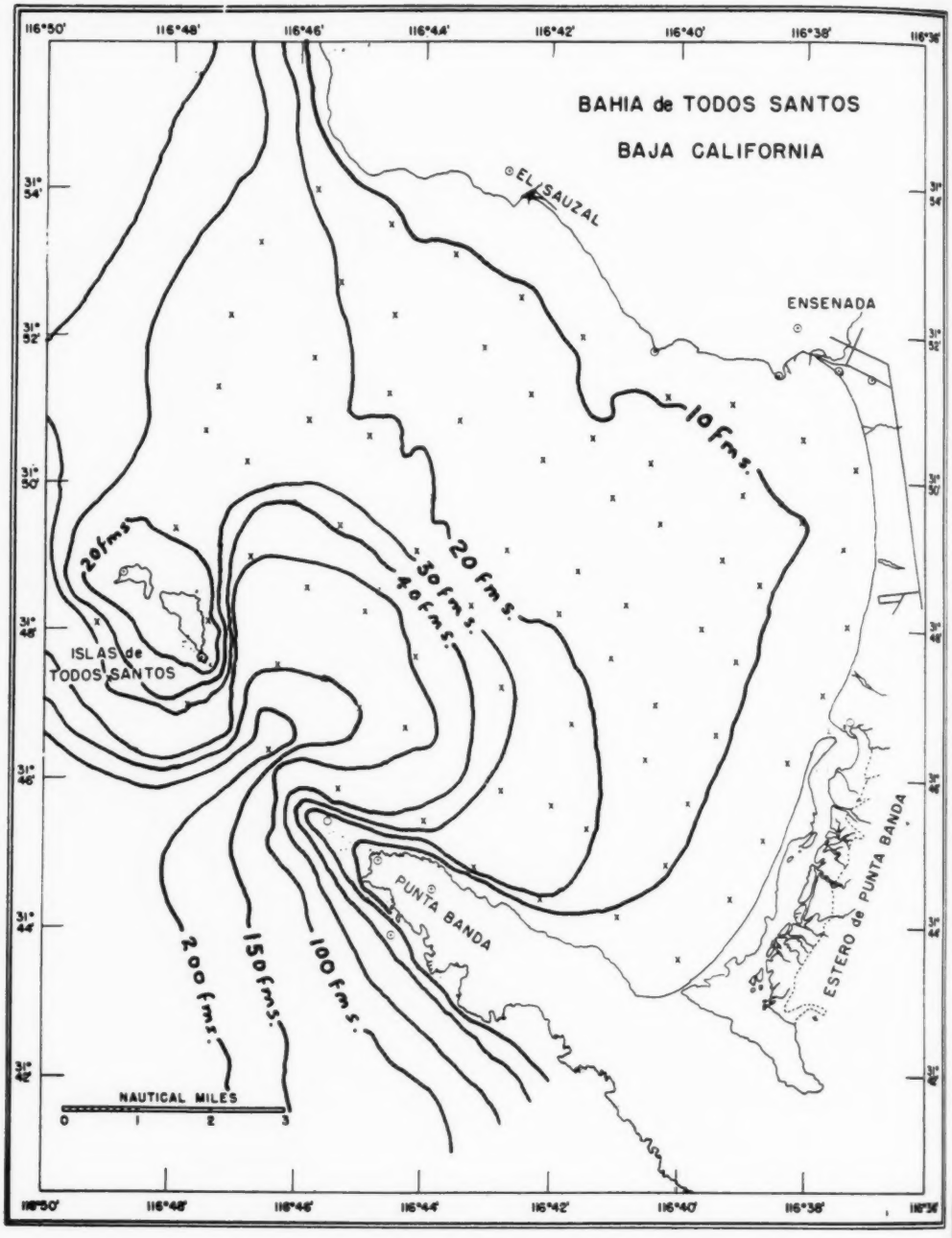
Nelson (1921, p. 85) reported a continuous submarine ridge connecting Punta Banda and the south Todos Santos Island. He also reported faunal and floral similarities between Punta Banda and the islands and concluded that they were once continuous. It appears that Punta Banda at some time in the past was continuous across the present deep trough and was connected



TEXT-FIG. *1*—Location of area and seasonal traverse.



TEXT-FIG. 2—Locations of stations in Todos Santos Bay.



TEXT-FIG. *3*—Bathymetric chart of Todos Santos Bay.

to the south Todos Santos Island. Numerous fathograms across the channel between Punta Banda and the islands show conclusively that there is no continuous ridge connecting them at the present time. Sharp steep ridges extend from the south island toward the southeast and from Punta Banda toward the northwest, but they slope steeply and terminate in a narrow trough-shaped channel. This deep channel heads into the depression just inside the islands and is well marked on the bathymetric chart (Text-fig. 3) by the 100-fathom contour.

The depression and the channel apparently are remnants of a submarine canyon. The more gentle inner slope of the depression appears to be a depositional slope in contrast to the steep structural and/or erosional slopes near the islands and off Punta Banda.

GEOLOGY OF SURROUNDING LAND

The geology of the area surrounding Todos Santos Bay is inadequately known. There are two exposures of sedimentary rocks in the area which have been examined: Upper Cretaceous sandstones, limestones, and conglomerates along the north side of Punta Banda and a thick wedge of sandstones and conglomerates on the north Todos Santos Island. Upper Miocene agglomerates, tuffs, and fresh-water sandstones have been reported on the mainland to the north of the bay (Beal, 1948, pl. 1), but have not been examined in the course of this study.

The Upper Cretaceous strata lie unconformably on the Cretaceous and pre-Cretaceous crystallines which constitute the mass of Punta Banda. They form precipitous cliffs which reach a height of 150 feet in some places. The top of these Cretaceous strata has been truncated by an old marine terrace and they are capped by alluvium. C. A. White (1885) first described the fauna from these strata and correlated them with the Chico group of California. Since this description, many new species have been added by Fairbanks (1893), Anderson & Hanna (1935, p. 7), and others, each concluding that these strata represent the Chico group of California. Beal (1948, p. 42) includes these strata in his Rosario formation along with the other Upper Cretaceous beds of Lower California.

The sedimentary strata along Punta Banda are not all equivalents of the fossiliferous strata described above. About midway along the Punta Banda exposures a fault separates the steeply-dipping sandstones and limestones of the Chico from horizontal strata of reddish fanglomerate-type deposits. These lie unconformably on the crystalline basement at the foot of the sea cliff and are non-fossiliferous. They consist of angular pebbles and cobbles in a matrix of fine- to medium-grained sandstones. These red beds appear in the Holderness well, near the mouth of the Tia Juana River, with a thickness of 269 feet. Similar red beds, 944 feet thick, occur beneath the well on Point Loma, California, drilled by the Borderland Exploration Company. According to Hertlein and Grant (1944, p. 39):

> " . . . these red beds may be a southern extension of the Trabuco formation in the Santa Ana Mountains, Orange County, Calif. . . . The red conglomerate resting on the diorite at Punta Banda, on the south shore of Todos Santos Bay, . . . may likewise represent the Trabuco formation. At that locality the fossiliferous Cretaceous is in fault contact with the red beds."

The sandstone and conglomerate exposures on the north Todos Santos Island were first reported by Lindgren (1888–89, p. 172). He correlated them with the Upper Cretaceous strata of Punta Banda. These exposures were examined and found to be non-fossiliferous. There appears to be no reason for correlating them with the fossiliferous sandstones and limestones of Punta Banda. Lithologically they are similar to the red fanglomerates but dip approximately 30° to the northwest. They are faulted against volcanic rocks at the south end of the island and are cut by numerous smaller faults along the length of the exposure. It is not possible to date these strata, but they appear to be the equivalents of the fanglomerates along Punta Banda. It is suggested that they may be near the distal end of the same alluvial fan. This suggestion is supported by their apparent structural position, by the fact that they are finer grained than the Punta Banda fanglomerates, and by the presence of sporadic mudcracks.

Beal (1948, pl. 1) shows extensive exposures of what he calls the Comondú formation, along the north shore of Todos

Santos Bay. These exposures have not been examined in the course of this study, but Beal states (op. cit., p. 74) that they contain "all volcanic rocks and terrestrial sediments of Tertiary age . . . ." He also states (op. cit., p. 74) that

> " . . . the bulk of the rocks so shown, however, are the product of a period of great volcanic activity, probably of Upper Miocene age . . . " "The formation is heterogeneous in composition and variegated in color. It includes large porphyritic and dense intrusives, rhyolite, andesite, and basaltic lava and tuffs, agglomerates, and mud flows, as well as conglomerates, sandstones, clays, and some limestones."

PREVIOUS STUDIES OF FORAMINIFERA

There has been no previous study of Foraminifera in the Todos Santos Bay area. The first detailed study of the ecology and depth zonations of Foraminifera off the coast of southern California was published by Natland (1933). He studied a series of samples extending from San Pedro Bay and across San Pedro Channel to Catalina Island. From these samples he was able to establish five faunal zones, as follows:

Zone I	Shallow, brackish-water lagoon (inter-tidal)
Zone II	Open ocean; depth range 14–125 ft.
Zone III	Depth range 125–900 ft.
Zone IV	Depth range 900–6,500 ft.
Zone V	Depth range 6,500–8,340 ft.

He suggests that temperature has a greater influence on the zonation of Foraminifera than depth.

Phleger (1951a) reported on a few foraminiferal samples off San Diego and recognized two general assemblages with the boundary between the two being at 100–200 fathoms. He also recognized shallow-water faunas which had been displaced down-slope into deeper water.

Butcher (1951) examined the Foraminifera of Coronado Bank and vicinity off San Diego. Four faunal facies were established; 130 m. to 260 m., 290 m. to 440 m. 490 m. to 550 m., and 730 m. to 810 m., with the major facies boundary at 390 m.–440 m. Temperature and salinity are considered by Butcher to be the most important ecological factors affecting these faunal, facies.

Crouch (1952) studied the Foraminifera from cores taken in the deep basins off southern California. He was able to establish four biozones which are more closely correlated with temperatures than oxygen or salinity variations:

T4	Depth range 900–2,000 ft.
T5	Depth range 2,000–4,000 ft.
T6	Depth range 4,000–7,500 ft.
T7	Depth range approx. 7,500 ft.—?

Crouch found that the foraminiferal faunas were uniform from the sill depths to the bottom of the basins which correspond to the nearly constant temperatures existing there.

Bandy (1953) studied the Foraminifera from three suites of samples from off San Francisco, off Point Arguello, and off San Diego. He recognized a north-south variation and a depth zonation in the foraminiferal faunas. Temperature was considered the most important ecological factor in north-south variation of the shallower-water faunas, but he offered no explanation for latitude variation in the deeper-water faunas where the temperature is nearly constant. Bandy suggests also that temperature is the dominant ecological factor controlling the depth zonations, but he points out that other factors may be important since depth zonations are present where no temperature gradation exists. Five depth zones were established:

Brackish (Polyhaline) zone
Middle-neritic zone 0–150 ft.
Lower-neritic zone 150–600 ft.
Bathyal zone 600–6,000 ft.
Abyssal zone 6,000 ft.

METHOD OF STUDY

FIELD METHODS

The field work was carried out during eight cruises. On the first cruise of February 5, 1952, sediment samples were taken from the entire area of Todos Santos Bay. During cruises on March 3, April 24, June 4, July 16, August 28, October 9, and November 10, sediment samples were obtained from a long traverse extending from shallow water in Todos Santos Bay to a water depth of 600 fathoms in the open ocean. On the last seven cruises samples were also obtained from the south side of Punta Banda.

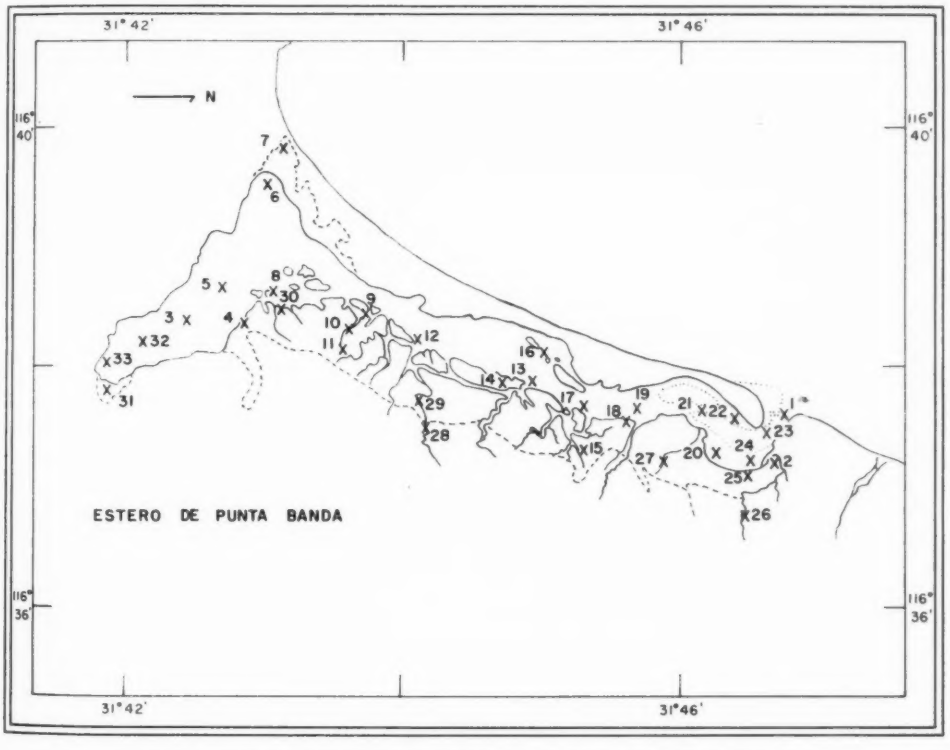
The first series of samples (February 5, 1952) were spaced at approximately 1-mile intervals on 8 traverses trending along the northeast-southwest axis of the bay (Text-fig. 2). The traverses were spaced about a mile apart, establishing a 1-square-mile grid pattern.

The stations on the seasonal traverses were spaced at 1-mile intervals to a depth of approximately 200 fathoms and at 2-mile intervals between 200 and 600 fathoms. The generalized locations of these stations are given in Text-figure 1. Actual locations of all stations are on record in the Library of the University of California at Los Angeles.

The samples taken from Estero de Punta Banda were spaced to obtain representative samples of all the environments in the tidal channels and marshes (Text-fig. 4). They were collected by hand in the marshes and by diving in the shallow channel.

A small coring tube similar to the one described by Phleger (1951b, pp. 3–5) was used where possible. It obtains a short, relatively undisturbed core $1\frac{3}{8}$ inches in diameter. In the areas of coarser sediments that could not be retained in the small coring tube, a sample was collected with a small orange-peel dredge, especially modified to prevent washing of the sediment en route to the surface (Phleger, 1952b, p. 320). This dredge has a capacity of approximately 100 cubic inches and samples a surface area approximately 10 inches in diameter.

The methods used to obtain a constant volume and area of surface sediment are extremely critical in studying either living or dead populations. A simple instrument was designed to assure constant volume sampling of all the cores and orange-peel samples. It consists of a 1 cm. length of brass tubing with the same inside diameter as the plastic core liners, and a knife edge of the same diameter pivoted on one side. As the cores were taken from the coring tube, the water in the top of the plastic liner was carefully siphoned off to within approximately one inch of the sediment-



TEXT-FIG. 4—Locations of stations in the Estero de Punta Banda.

water interface. The remaining water was then poured into a sample jar, and the core material was extruded into the constant volume sampler just described. The top one centimeter was cut off with the knife edge and was placed in the sample jar with the water.

The orange-peel surface samples were collected in a similar manner. As the orange-peel samples were brought on deck, the canvas cover was opened at the top and a short piece of plastic core liner was inserted into the sediment. This was extruded, and the top 1 cm. was cut off using the constant-volume sampler. The major difference between this type of sample and the small core sample is that the water immediately above the bottom is lost in the orange-peel sample. This water, which may contain living specimens, drains through the sample as it is brought on deck, and any specimens which may have been suspended in the bottom water tend to be trapped at the surface of the sediment.

The use of two different methods of obtaining bottom samples introduces a possible source of error in counting or estimating populations of Foraminifera. Inspection of the total populations and percentage populations of individual species in adjacent stations from which the two types of samples were obtained shows no appreciable variation that would not be expected within normal faunal variations. Distributions of sediments over the area of Todos Santos Bay (see following discussion) show normal variations and support the reliability of the samples.

All of the samples were preserved in a 10% solution of neutralized formalin. A small amount of sodium carbonate was placed in the samples to maintain an alkaline solution as the neutralized formalin will become acidic with time (see following discussion).

The stations in Todos Santos Bay were located by two-angle sextant fixes and bottom topography. Station positions outside the bay were located by dead reckoning and peloris fixes when the visibility permitted.

In addition to sediment samples, bathythermograph observations, measurements of surface water and sediment temperature, and depth soundings were taken at each station. Three times during the period of sampling, February 4, June 4, and October 9, a bathythermograph survey was made of the entire bay. Detailed temperature data also were obtained along two short traverses normal to Punta Banda on both the north and south sides at each season of sampling.

Water samples for salinity were taken at most stations in the Estero de Punta Banda and at selected stations in Todos Santos Bay.

LABORATORY WORK

Living populations were counted in 215 sediment samples. Dead populations were counted in 110 samples and sediment size analyses were run on 70 samples.

Living populations.—The living populations were determined by the rose bengal staining method (Walton, 1952). "Living" is used throughout this paper to indicate those specimens which contained protoplasm when collected. The word "dead" refers to those foraminiferal tests which did not contain protoplasm at the time of collection. The reliability of these assumptions is discussed by Walton (op. cit., p. 59). Each sample was washed through a bank of five sieves, 1 mm., 0.177 mm., 0.125 mm., 0.088 mm., and 0.062 mm. The fractions of the sediment finer than 0.062 mm. were caught in a basin below the sieves. This wet sieving procedure served three purposes: (1) it removed the fine sediment from the fractions to be examined for Foraminifera, (2) split the samples into manageable fractions for population counts, and (3) divided the sediment into size classes from which sediment analyses could be made.

It had been determined previously by experimentation that most of the Foraminifera were concentrated in the 1–0.177 mm., 0.177–0.125 mm., and 0.125–0.088 mm. size fractions. The size fractions above 1 mm. and those below 0.088 mm. contained Foraminifera attached to larger sediment particles and juvenile forms respectively. All coarser fractions were examined, but it seemed impractical to attempt to identify the juvenile forms in the finer fractions. Thus, the living populations from the three intermediate size fractions, 1–0.177 mm., 0.177–0.125 mm., and 0.125–0.088 mm.,

were counted separately and combined to obtain the total living populations. The total living populations from each of the samples examined are presented in Tables 1–3. The living populations of the size fractions are not presented for the sake of brevity but are on record in the Library of the University of California, Los Angeles, and the Scripps Institution of Oceanography, La Jolla, California.

As each of the samples was washed, the size fractions to be examined were placed separately in a specially-designed cylindrical sieve (average opening 0.074 mm.) and immersed in the rose bengal stain solution. The staining time is not critical. The protoplasm stains almost immediately, and only the intensity of the coloration varies with the length of time the sample is left in the solution. Approximately 20–30 minutes has been found to be sufficient staining time to obtain good coloration of the protoplasm.

The sample was then transferred to a gridded, plastic counting tray. This tray has an opaque background, and the red-colored living specimens are easily distinguished from empty foraminiferal tests and inorganic sediment particles.

The dead populations were counted along with the living populations from the wet samples except where the dead populations were very large. In the latter case it was necessary to dry the fractions of the samples and split them mechanically in order to obtain workable populations. The Otto Microsplit was used for this purpose. This small mechanical splitter has been tested statistically and shown to produce aliquots which for all practical purposes can be considered equal (Otto, 1933). The total populations of the samples from which dead counts were made are presented in Tables 4 and 6. The dead populations of the three size fractions are not presented for the sake of brevity but are on record in the Library of the University of California, Los Angeles.

SIZE ANALYSES OF SEDIMENTS

Size analyses of the sediments were obtained from the initial wet sieving. The size fractions from which the population counts were made were dried and the sediment parameters were calculated according to the procedure described by Inman (1952). The analyses obtained by wet sieving were compared with both settling tube and dry sieve analyses of the same samples and were found to be approximately comparable.

The coarser fraction of the sediments (greater than 0.177 mm.) were dry-sieved through a coarser bank of sieves of $\frac{1}{2}$ ϕ intervals in the samples where they constituted more than 15% of the total sample. The samples in which the fine fractions (smaller than 4 ϕ [0.062 mm.]) constituted more than 15% of the sample (by weight) were analyzed by the pipette method (Krumbein and Pettijohn, 1938, pp. 162–167).

Phi notations of Krumbein (1936) have been used in the sediment size distributions considered in this study where $\phi = -\log_2$ of the diameter in millimeters. The three primary descriptive parameters suggested by Inman (1952) have been used. These three measures are the phi median diameter ($M\phi$), phi deviation measure ($\sigma\phi$), and phi skewness measure ($\alpha\phi$), and are defined as:

$$Md\phi = \phi 50$$
$$\sigma\phi = \tfrac{1}{2}(\phi 84 - \phi 18)$$
$$\alpha\phi = \frac{M\phi - Md\phi}{\sigma\phi}$$

where $\phi 18$, $\phi 50$ and $\phi 84$ represent the 18, 50 and 84 percentiles and $M\phi$ the phi mean.

TEMPERATURE AND SALINITY DISTRIBUTION

The annual variation in the average surface temperatures existing at the seasons of collection in Todos Santos Bay is approximately 10.0°F. There is a recorded minimum during March of 57.0°F. and a maximum of 67.8°F. during August. These temperatures correspond generally with the average maximum and minimum temperature observations made at La Jolla, California, over a period of 25 years.

During February, March, and April, the surface temperatures are strikingly uniform over the bay. The highest temperatures during these months occur around the inner part of the bay and along the mainland. During June and July, the surface temperatures inside Todos Santos Bay are considerably warmer than during the previous

TABLE 1—OCCURRENCES OF LIVING BENTHONIC FORAMINIFERA IN ACTUAL NUMBER OF SPECIMENS. ALL FRACTIONS. (PER UNIFORM SIZE SAMPLE) (PT.)

| STATION | 0-34 | 0-72 | 0-73 | 0-127 | 0-150 | 0-277 | 0-357 | 0-467 | 0-52 | 0-92 | 0-93 | 0-111 | 0-53 | 0-110 | 0-348 | 0-94 | 0-95 | 0-151 | 0-241 | 0-288 | 0-358 | 0-459 | 0-54 | 0-91 | 0-108 | 0-341 | 0-51 | 0-71 | 0-87 | 0-105 | 0-152 | 0-359 | 0-90 | 0-105 | 0-280 | 0-346 | 0-153 | 0-243 | 0-369 | 0-75 | 0-89 | 0-96 | 0-97 | 0-150 | 0-151 | 0-244 | 0-245 | 0-246 | 0-247 | 0-248 | 0-249 | 0-250 | 0-251 | 0-252 | 0-253 | 0-254 | 0-255 | 0-256 | 0-257 | 0-258 | 0-259 | 0-260 | 0-261 | 0-262 | 0-263 |

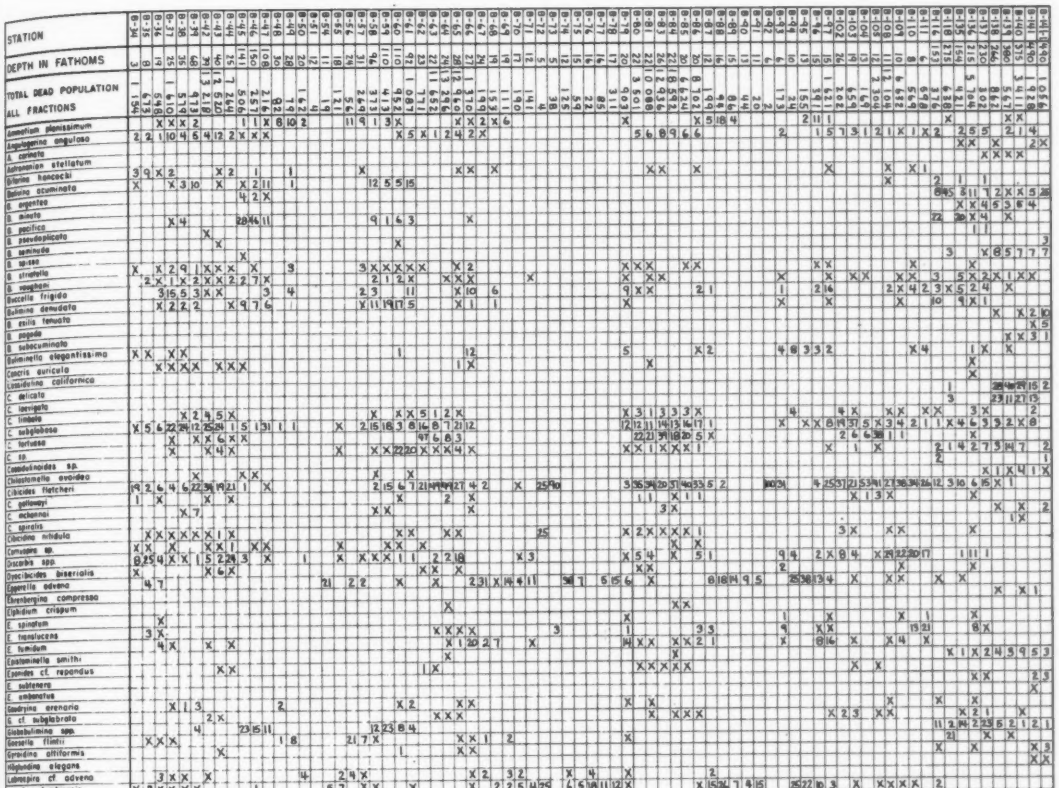
TABLE 2—OCCURRENCES OF LIVING BENTHONIC FORAMINIFERA IN ACTUAL NUMBER OF SPECIMENS. ALL FRACTIONS. (PER UNIFORM SIZE SAMPLE) (PT.)

STATION	8-244	8-471	8-70	8-78	8-131	8-282	8-362	8-366	8-68	8-103	8-344	8-50	8-84	8-86	8-215	8-82	8-80	8-81	8-155	8-132	8-142	8-56	8-64	8-67	8-237	8-83	8-102	8-66	8-44	8-65	8-149	8-48	8-57	8-363	8-338	8-211	8-42	8-43	8-156	8-252	8-267	8-306	8-448	8-381	8-330	8-133	8-361	8-58	8-411	8-90	8-445
DEPTH IN FATHOMS	16	16	17	17	17	18	19	19	19	19	19	20	20	20	20	20	22	22	22	22	23	24	24	24	25	25	26	27	28	28	29	30	31	31	35	35	38	39	40	40	45	47	54	55	62	64	68	76	80	110	118
TOTAL LIVING POPULATION ALL FRACTIONS	102	55	27	22	26	32	443	63	42	33	136	381	203	115	343	91	390	67	117	105	55	113	154	93	114	124	60	105	44	230	29	91	117	164	155	423	101	227	46	169	255	47	93	187	124	83	103	114	80	86	63
Ammodiscus pacificus																																										10	5								
Annotium planissimum	2					1	6	1		1		1		1		5	3			16	2		2		2	1			4	1	2		11	8		3	1		13		7	5	4	1		9		32	1					
Angulogerina angulosa					1						3			6	3			3	3	2					3		5	3	5	2		1	4				2									5					1		
Bolivina hancocki														2												1			4																							
Bolivina argentea																																																				
B. minuta																																																			
B. pacifica							2				9				8			1											2			1		4	1	4	6	3		4			1	4	5	50	100		1	4	5	9	3	8	7
B. acuminata														1	6																		1	3	5	6	2		2	2	20	9	8	3	12	24	2	3	3	15	14	9	11	4	2
B. spissa									1				1	2	4			1		1	4					11			7		7	16		2	1	10			1	1		1	1		2	2	8		6		1			
B. striatella														1																		2		2																	
B. vaughani																																																				
Buccella frigida						2		3			1	1			4	3	1			3						5		1						2	1	2	2			1				3	4		1	1				
Bulimina denudata															2											1			1					2		1	1		5		1	2	1			9		20	15	27	10	4
B. exilis tenuata																																																			
Bulimonella elegantissima				4															3																																		
Cancris auricula														1				1							1						1	5			1			2	1			1	1	4	15	1		1				
Cassidulina sp.																															5								5	3						2		1	1			
C. delicata																																																			
C. laevigata																																																			
C. limbata													6	1				3		7		3				25	5											11			2			1								
C. subglabosa										16			16	5		4	6	1	6		3	12		6	34	13	1	17		2	4		4		2		1			3	1	4		6	4	2	1				
C. tortuosa										16		2	2			6	5	6	11		31	21		1	5			1									14															
Cassidulinoides sp.																																																			
Chilostomella ovoidea																																												1	6		6			2	
Cibicides fletcheri								7		47			17	4		28	14	10	13		6	81			26	21		8				3		6	6	3							4		11	2	
C. galloway										1			1					1	2			2											1																	
C. mckannai																			2						1	3							4									6	2	4		2					
C. spiralis																																																			
Cibicidina nitidula										2			2	1				1	1			2		1	3	1				2											1										
Cornuspira sp.								1														1		8								2												2		1				
Discorbis spp.			1					4	5	2		4		1				1											15				1													1					
Dyocibicides biserialis																		1				3			2																										
Eggerella advena	9	5	1		4		1		1	3		1		3	4				1	1				1								2							1					1							
Elphidium spinatum																																																			
E. translucens	26							1					1	1	1																																				
E. tumidum	2			3				3	1				4		6											2	1	1	1																						
Epistominella smithi																																																			
Eponides cf. repandus																				1																																
Gaudryina arenaria												2																							1	1			2					5		2					
G. cf. subglabrata										5			1						2			1			1			1																							
Globobulimina spp.																																		1	2	7	4				4	5	5	4	9	14	52	5	33	9	25	24	8	10	16
Gomesella flintii							2				6				8	2			2	1	2		2		6	2			6	1	5		6	3	23	1	14	1		44		6	32		1	14		4		1			5
Hoglundina elegans																																																			
Lobospira cf. adveva			1		1				1			13	2							2					4	6						1	1		3	7					7										
L. cf. columbiensis	19	2	3	9	2	5		1	1		1	1	1	3		25	1	1		2	1	2	2		2	1	2	1		1		5	1		6	9	6	9	5		5		3	6	8	6	12	6	2		1	5	3			2	4
Lagenidae													2									1				1			1		2										3									2	1			
Leoestomum pseudobeyrichi																																																			
Miliammina fusca										1			1		3										2																												
Miliolidae					1					15			2	1			2		3			3						4																								
Nonionella basispinata	21	8		1	2		2	48	9		33	9	25		19	10	12	2	2	2	11	50		2		1	1		3	10	1			8	14	4	39	8		1	28	31	4			1		1			4
N. miocenica stella	8	26	2				16	50	9	1		34	5		6	17	11		1		9	33			3	13	2		33	4	36		4	24	42	17	17	11		34		58	33	14		6	2	44	45	16	34		5	24	8	6		14
N. sp.																																		1	1	7		2							4		19							5
Planorbulina mediterranensis																									1		1																								
Planulina exorna						1				4				3			2	1	4	3		1		1		8	4		2				2				3		4	3							1		1		
Polymorphinidae														1	1	2									1		2																							
Protoknina atlantica	2	12	5	9	7	14	4	2	3	2	12	1	9	4	24	1	3	13	4		1	3	12	6		4		2	2	3	1		2		5		3	3		3	5		3			1			2	1	5	2
P. sp.	1														7				2					2	1			1		2	6		1		2	1	6		3			1	3	2		24	1		1			
Pullenia salisburyi																															1																		1		
Quinqueloculina sp.																																																			
Recurvoides spp.									2										3		1		3				1	2	4		8	13	1	3	6		15			2			9		2	1		1	
Reophax agglutinatus												2																																				3				
R. curtus			2			15	1			1		6			6				5	2			6	4			6	5	14		11	12	2	5				3													
R. gracilis						2	3								9			1			1				1						1	4	5	2	1	2			1		3	4	6	19	2	3	1		4		1	
R. horrida																																														2						1
R. scorpiurus			1	2		1		4		4		2	6	8		2	5	8			25	2		3	14	4			5	8		33	10	3	1	2	1		8		6	4			2						
R. sp. 1																																																			
Rhabdammina cf. abyssorum												X									X															X		X	X												
Robertina charlottensis																2																								6			2			1						
Rotalia spp.							1	8	1		17			7	6	12		7	1	1	8				14		1	4	3	2	2		20			3				1	2										
Textularia cf. schencki										1			1	1	1				2		2					3									4		5		1	3		2					1		1	1		
T. cf. earlandi																				1																	2														
Triloculina sp. 1	6										10			2		1	1	1									1	2								4				14											
Trochammina kellettae	1			4			2									2	1					3				3	3																								
T. pacifica	5	2	11	1		25	3		8	23	8	1	3	2	10		10	4	2	2			2	1	8	2		8	8		7	9	8	1	2	4	3		1		1	2	2			2					
Uvigerina peregrina vars																		1																												1		2		23	2	11	1	4
Valvulineria araucana																																																			
V. inaequalis																																																			
Virgulina bramlette																																																			
V. seminuda																																																			
Unidentified forms								7			10		5											2	11	4			11	13				11	7	13	2			2					1						
Planktonic forms							4																		6							1																			

TABLE 3—OCCURRENCES OF LIVING BENTHONIC FORAMINIFERA IN ACTUAL NUMBER OF SPECIMENS. ALL FRACTIONS. (PER UNIFORM SIZE SAMPLE) (PT.)

STATION	9-253	9-292	9-337	9-293	9-364	9-157	9-134	9-365	9-254	9-46	9-161	9-135	9-371	9-336	9-484	9-317	9-310	9-158	9-502	9-326	9-336	9-214	9-485	9-136	9-235	9-486	9-159	9-318	9-257	9-319	9-286	9-347	9-380	9-141	9-295	9-160	9-138	9-118	9-297	9-319	9-258	9-488	9-369	9-298	9-489	9-320	9-140	9-139	9-259	9-440	9-321	9-141	9-249	9-142	9-143	9-144	9-145	9-146	9-147	9-148
DEPTH IN FATHOMS	120	120	122	125	127	130	141	147	148	150	153	154	155	165	167	169	175	177	187	189	195	203	203	215	215	215	217	219	220	230	245	245	248	250	250	266	266	275	297	320	325	325	340	350	360	365	375	380	400	420	430	450	450	450	450	450	450	450	450	450	450
TOTAL LIVING POPULATION ALL FRACTIONS	170	40	167	88	39	25	102	72	77	17	16	8	32	42	42	11	13	2	23	45	31	93	13	8	35	33	19	2	11	14	13	11	13	7	28	39	14	37	32	18	53	48	31	127	19	40	108	108	30	24	23	29	4	15	2	1	1	1	1	1	1	1
Ammodiscus pacificus																																																																				
Ammotium planissimum			2		3		1									1	5	1		1	2	1			2			1	3		1		1					2		6	8		2			1																			
Angulogerina angulosa																						1	1																																												
Bifarina hancocki																																																																	
Bolivina argentea																1	1			1	2	2	3	2				2		1						1			66		18																											
B. minuta																																	1	3	1	2					1							1	1		1		2												
B. pacifica	35	13	28	21	13	1	32	9	22	10			1	2	1	7		3		4	1	11		1	1												2			1								1																		
B. acuminata	2		2	3			1			1				1				1					1	1		1								1	1																															
B. spissa																				1							1						1	1			10		8	8	4		13	9	31	2	13	18	31	11	10	11	4	1		2	2	1								
B. striatella																										1																																								
B. vaughani							1																		1																																							
Buccella frigida			7																																																															
Bulimina denudata	22	1	9	7	7	3	13	6	1	3	5	5	2		1					1				1																						6																					
B. exilis tenuata																																																																		
Buliminella elegantissima							1								1																						1																												
Cancris auricula				1			1						4									8	2														2																												
Cassidulina sp.	1					1																		1															1		7	3		2		1	7	6	6	2	4	3	2	5	3		1	1								
C. delicata																																			1			6		3			7		1	19		1		3		4												
C. laevigata																																																																			
C. limbata																																																																		
C. subglobosa	1			5		5			1																																																										
C. tortuosa																																																																		
Cassidulinoides sp.													2									2																																														
Chilostomella ovoidea	1	1						3		1			1									8		1		1								1	2			9	3	4	4	7	17		4	4	12			1														
Cibicides fletcheri																								1																																									
C. galloway i																																																																		
C. mckannai																																																																	
C. spiralis																																																																	
Cibicidina nitidula																																																																	
Cornuspira sp.																																																																
Discorbis spp.																																																																
Dyocibicides biserialis																																																															
Eggerella advena																																																																	
Elphidium spinatum																																																															
E. translucens																																																																	
E. tumidum																																																																
Epistominella smithi																										1													1		2		1		2		1			1														
Eponides cf. repandus																																																															
Gaudryina arenaria	2																																																														
G. cf. subglabrata																																																																
Globobulimina spp.	79	16	5	9	23	4	9	38	17	6	4	2	5	3	3	12	17	16	4	2	2	4	11	2	4	2	18	28	6	12	1	1	9		14		6	3	3	1		1	1	2	1	1	21	2		1		2	1								
Goesella flintii				3	3	1				1	1			1	4		3						4	8	5	1	3				1	3	5	2	1	3	3	3		23			1				2	1														
Höglundina elegans																																																													
Labrospira cf. advena																																																													
L. cf. columbiensis	3		3	1	1					2	1											2		1												1																											
Lagenidae											1																																																			
Laxostomum pseudobeyrichi																																																												
Miliammina fusca																																																													
Miliolidae																				2	2																																									
Nonionella basispinata			2																																																										
N. miocenica stella	3	4	17	2	7	5	7	3			1						1										1																																			
N. sp.	14	3	27	7	1				36	18				3	14	13	32	2	2		11	7	1	1	3		2					2	2	1		1			1	8	1		9																			
Planorbulina mediterranensis																																																												
Planulina exorna																																																													
Polymorphinidae																																																												
Proteonina atlantica				1		1						1										1																																								
P. sp.		1									3							1	1														3		2		1	3				11	2	30	1	6	3			1										
Pullenia salisburyi																						3																														1										
Quinqueloculina sp.																																																												
Recurvoides spp.							1	1							1																		1			5								2		2												2	
Reophax agglutinatus				3																																																									
R. curtus																																																															
R. gracilis	2	1	2	1		1	1	1	1		2		2		2		1	1	2	3		1		1	2		2									2							1		1															
R. horrida															1					1	1				1										1		10			5	9	1		1																
R. scarpiurus																																																												
R. sp. 1																																										1	1	1	2		3	1			10	1					6	1	45
Rhabdammina cf. abyssorum																																																												
Robertina charlottensis			1																																																										
Rotalia spp.																																																												
Textularia cf. schencki																																																											
T. cf. earlandi																																																											
Triloculina sp. 1																																																										
Trochammina kelletae																																																										
T. pacifica	1									3																																																	
Uvigerina peregrina vars	4		9	8	2		3			1			2	1							1	3					1	6	6	5	3		4		10		3	1	1	2		3	3	2	1	1	3	2									1	2
Valvulineria araucana																						4	8											2			1	4	3		5		1	1	4	2	1		3										
V. inaequalis																							1		1									2				1			1		2		1			2										
Virgulina bramletti					1									3				1				1														3		6		4				1														
V. seminuda									5							1	1				1	1	2		1		1	3					4		1																							
Unidentified forms				1			1					1										7												2	6	2										4	15	3	2		1							
Planktonic forms							8						1																																															

TABLE 4—OCCURRENCES OF DEAD BENTHONIC FORAMINIFERA IN PERCENT OF TOTAL POPULATION. ALL FRACTIONS. X LESS THAN 1%.



months. They average about 61.0°F. but reach 65.0°F. around the inner part of the bay and along Punta Banda. The mixed layer is shallow; only 5–15 feet during these months.

The most interesting feature of the temperature distribution in June and July is the occurrence of upwelling on the south side of Punta Banda. During February, March, and April the difference in temperature between the north and south sides of Punta Banda is small, averaging only a few degrees. In June the temperature difference between the north and south sides of Punta Banda is 9–10°F. Dr. Carl Hubbs of the Scripps Institution of Oceanography (personal communication) has found temperature differences as great as 21°F. During July this cold, upwelled water extends along Punta Banda as far as the Todos Santos Islands and extends around Punta Banda a short distance into Todos Santos Bay.

The highest surface temperatures of the year occurred in August. Temperatures as high as 71°F. occurred in the inner part of the bay. The water on the south side of Punta Banda increased to 59°F., but there was approximately 10°F. differential across the point.

During October and November the water temperature in the bay gradually decreased to approximately 61°F. Upwelling on the south side of Punta Banda apparently diminished during these months and the water temperature was approximately the same as that of the bay water.

The influence of the warmer waters from the Estero de Punta Banda on the open bay waters is noticeable during the spring and summer months. The water in the Estero de Punta Banda flows in and out with the tidal cycle and the warmest water in the bay during these months generally occurs near the mouth of the estero. The tidal range in this area is approximately 3.8 feet. The water temperatures in the shallow estero are quite variable and range from approximately 60.0°F. near the mouth to more than 85.0°F. near the head. Estero temperatures were only measured during November, 1951, along with the collection of the estero samples and no seasonal data are available.

Salinity measurements from samples corresponding with the seasonal traverse in the bay show fairly uniform surface salinities of approximately 33.40°/$_{oo}$. Since these samples were collected during February they probably represent minimum salinity values, because this is the rainy season in this region. The seasonal variations of salinities in the open ocean off Punta Banda show variations from approximately 33.40°/$_{oo}$ in the winter months to approximately 33.70°/$_{oo}$ during the spring and summer months, according to Paul Horrer (personal communication). It is believed that the range of salinity given is representative of the range occurring in Todos Santos Bay.

The salinity measurements in the Estero de Punta Banda show greater variation. Near the mouth of the estero the salinities range from 33.40°/$_{oo}$ to 33.98°/$_{oo}$. The channel stations all show salinities between 33.63°/$_{oo}$ and 34.00°/$_{oo}$. The highest salinities occur near the head of the estero and from the tidal channels away from the main channel. These salinities are all greater than 34°/$_{oo}$ and range up to 37°/$_{oo}$. The salinities in the Estero de Punta Banda probably vary considerably during the various seasons. Rapid runoff must lower the salinity considerably during the winter rainy seasons. During the spring and summer months the salinity would probably increase due to high temperatures, no precipitation, and evaporation.

THE SEDIMENTS

SEDIMENT TYPES

Seventy samples were analyzed from Todos Santos Bay. Size analyses of the sediments were made from all the stations listed on Text-figure 2 with the exception of stations B-40, B-41, B-82, B-98, B-99, B-11, B-101, B-106, and B-107, from which no samples were obtained. The sediment samples were subjected to the standard methods of mechanical analysis, and from these data phi median, phi deviation, and phi skewness were calculated. These parameters are presented in Table 5. The sediments of the area fall generally into three groups based on a plot of the phi median against phi deviation and phi skewness (Text-fig. 5). The geographic distribution of

TABLE 5.—SEDIMENT SIZE DISTRIBUTIONS

Sta. no.	Depth (fms.)	Mdϕ	σϕ	αϕ
B-34	3	2.37	.87	.18
B-35	8	1.76	.50	0
B-36	19	3.20	.40	0
B-37	25	2.98	.70	−.01
B-38	35	3.68	.60	−.33
B-39	68	3.85	1.40	0
B-42	39	.97	1.43	−.05
B-43	40	.25	1.10	.26
B-44	25	−.50	3.10	−.09
B-45	141	5.95	1.80	.13
B-46	150	5.41	1.84	.40
B-47	108	5.45	1.36	.25
B-48	30	4.28	.72	.22
B-49	28	3.75	.70	−.06
B-50	20	3.27	.34	.11
B-51	12	2.92	.38	−.10
B-52	6	3.57	.25	.04
B-53	7	3.27	.24	−.05
B-54	11	3.22	.34	0
B-55	18	3.50	.29	0
B-56	24	4.27	.46	.23
B-57	31	4.65	.61	.32
B-58	96	5.06	1.26	.47
B-59	110	5.45	1.70	.34
B-60	110	5.85	1.55	−.05
B-61	92	5.23	1.11	.23
B-62	23	1.45	.50	0
B-63	22	2.16	.60	.03
B-64	24	2.10	.70	−.04
B-65	28	3.49	.72	−.48
B-66	27	4.20	.31	.26
B-67	24	3.99	.36	.11
B-68	19	3.91	.28	.08
B-69	19	4.02	.42	.28
B-70	17	3.57	.19	0
B-71	12	3.42	.61	−.05
B-72	5	3.10	.33	0
B-73	5	2.80	.28	0
B-74	12	3.70	.32	0
B-75	15	3.65	.32	.03
B-76	16	3.63	.27	.14
B-77	16	3.77	.29	0
B-78	17	3.92	.34	0
B-79	20	3.98	.37	.03
B-80	22	2.47	.50	−.14
B-83	26	1.92	.50	−.18
B-84	22	2.40	.73	−.05
B-85	20	2.40	.57	−.07
B-86	20	3.51	.76	−.06
B-87	12	3.93	.34	−.06
B-88	16	3.73	.38	0
B-89	15	3.70	.44	.12
B-90	13	3.61	.36	.33
B-91	11	3.62	.34	−.03
B-92	6	3.20	.28	−.03
B-93	6	3.48	.30	−.07
B-94	10	3.65	.41	.09
B-95	13	3.72	.50	.12
B-96	15	3.91	.48	.16
B-97	15	3.93	.39	−.01
B-102	26	2.25	.48	−.12
B-103	19	2.49	.42	−.05
B-104	13	2.55	.65	−.23
B-105	12	1.34	.93	.24
B-108	11	3.65	.38	−.10
B-109	10	3.44	.50	−.10
B-110	8	3.87	.49	.02
B-111	6	3.47	.45	−.02
B-116	153	5.80	1.50	−.03
B-118	275	5.46	.78	−.29

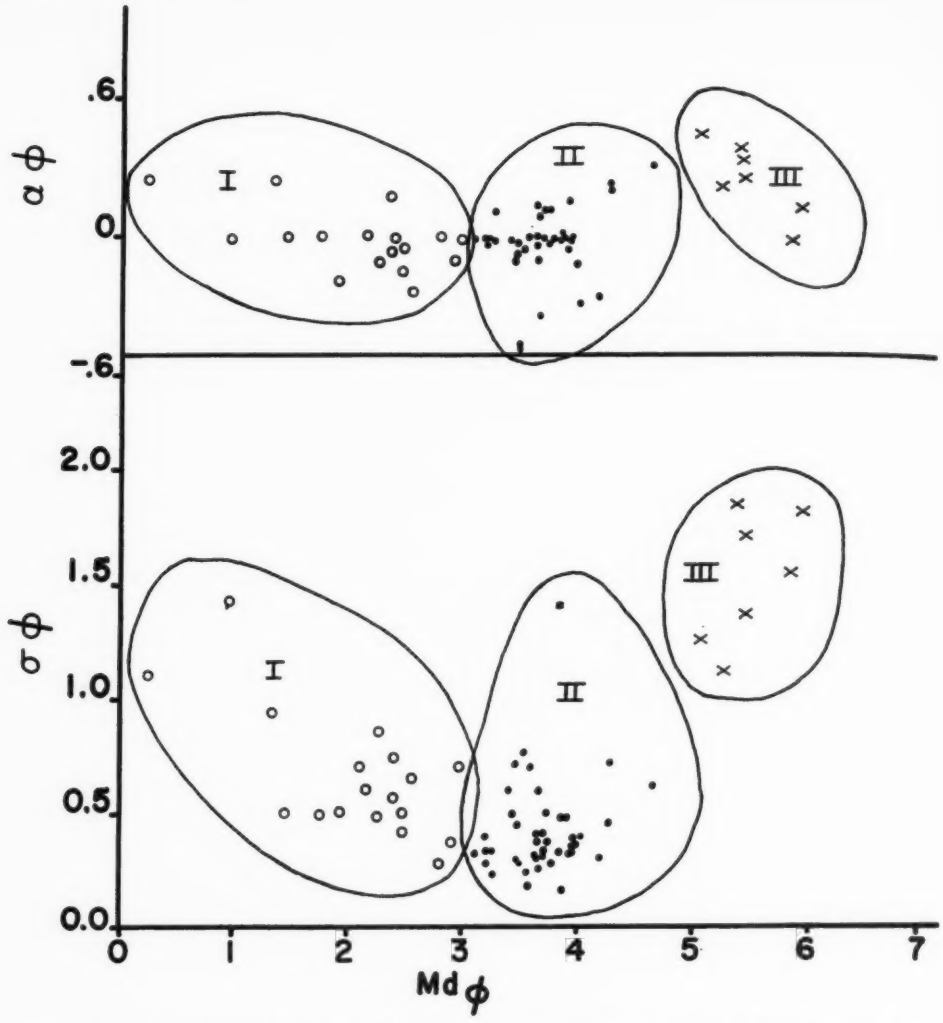
these groups is presented in Text-figure 6.

It should be pointed out that in most instances the amount of sediment available for particle-size analysis was less than 10 grams. It is believed, however, that the descriptive parameters obtained from the particle-size analysis are adequate for the purposes of this study.

The sediments of Group I occur in a strip between the Todos Santos Islands and the mainland on the north side of the bay. They also occur along Punta Banda and at one station near the mouth of the Estero de Punta Banda. This group of sediments is relatively coarse. The Mdϕ ranges from less than 1ϕ to 3ϕ, the sorting is poor, the phi standard deviation is generally greater than 0.50ϕ, and the sediments are generally skewed toward the coarser sizes. They are most generally brown in color, and many samples contain well-rounded pebbles and cobbles.

Microscopic examination of the Group I sediments shows very large populations of Foraminifera. The pebbles and cobbles are encrusted with bryozoans and attached Foraminifera suggesting little or no transportation or agitation of the bottom at the present time. Glauconite occurs in low percentages in the form of internal molds of Foraminifera and suggests extremely slow sedimentation. Fine detrital sediments occur in most of the samples along with the more predominant coarser sizes and cause slight bimodal tendencies in some samples. All of the samples contain abundant shell fragments (other than Foraminifera) and broken echinoid spines.

The Group II sediments cover most of the bay area with the phi medians ranging for the most part between 3ϕ and 4ϕ. They

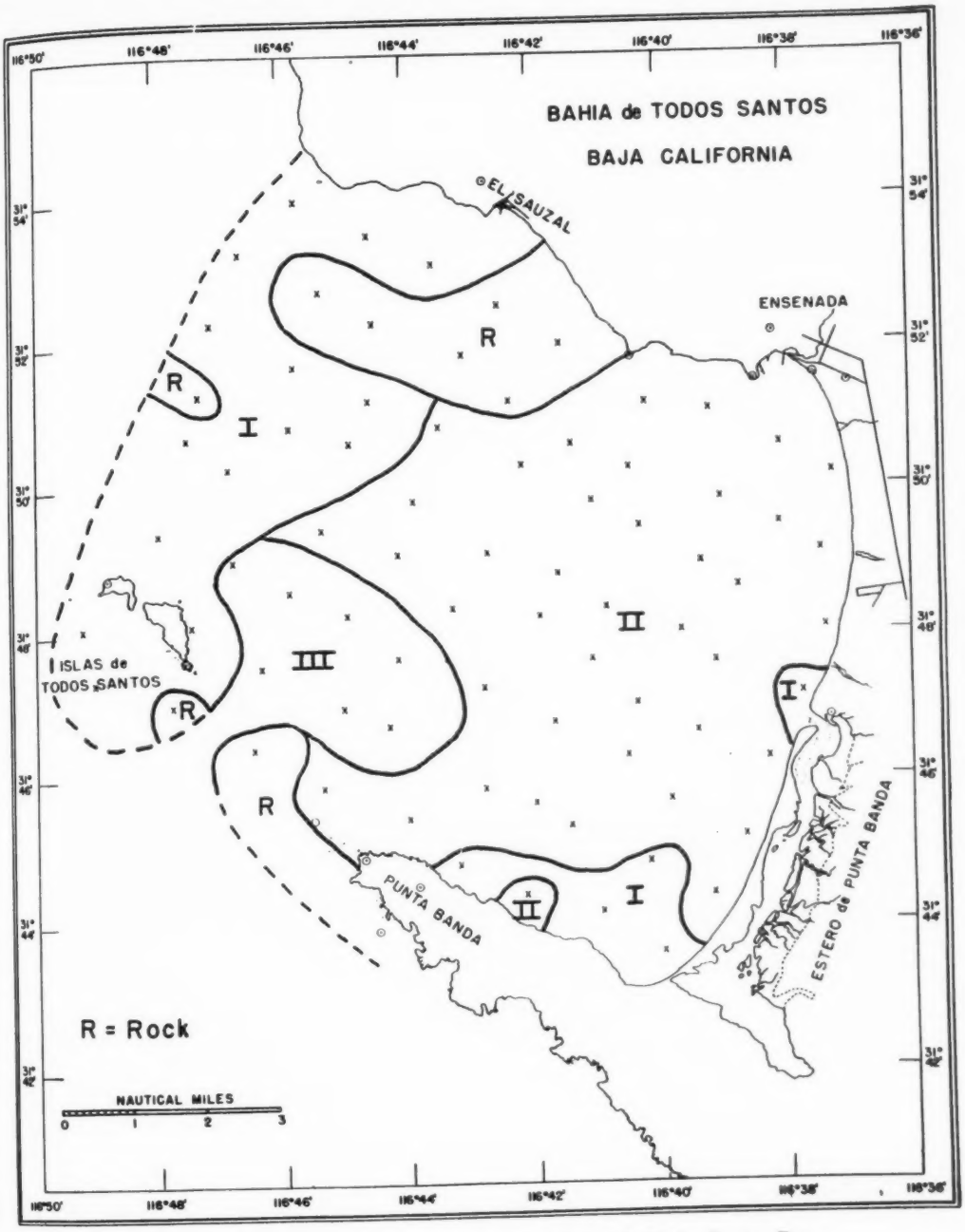


TEXT-FIG. 5—Sediment groups in Todos Santos Bay based on plot of Phi median (Mdϕ) against Phi deviation ($\sigma\phi$) and Phi skewness ($\alpha\phi$).

are well-sorted with the phi deviations generally below 0.50ϕ and there is little skewness. These fine sands and silts are grey in color and consist of angular quartz grains, with small percentages of dark minerals. The mica concentration generally increases offshore. The sediments generally contain little or no organic remains other than Foraminifera.

The Group III sediments occur just seaward of the Group II sediments over a depth range from 100 to 200 fathoms. Their medians are greater than 5ϕ, they are poorly sorted (phi deviations greater than 1ϕ), and they are generally skewed toward the finer sizes. They contain few organic remains other than Foraminifera. They have a high mica content and show signs of intense reworking by detritus-feeding organisms, principally worms. Careful washing of these samples produced large concentrations of fecal pellets in the coarser size fractions.

No sediment samples were obtained from



TEXT-FIG. 6—Areal distribution of sediment groups in Todos Santos Bay.

stations within the areas denoted by "R" in Text-figure 6. From stations B-100, B-101, and B-106 only pebbles and cobbles of sandstone, tuffs, and agglomerates encrusted with living organisms were obtained. No samples were obtained in numerous attempts at stations B-40, B-41, B-62, and B-107. A coarse brown sandstone was cored in place at stations B-98 and B-99. These rock samples contained no fossils. The areal extent of this submarine sandstone outcrop is not known, but some of the pebbles and cobbles from stations B-100, B-101, and B-106 have a similar lithology.

SOURCE OF BAY SEDIMENTS

The only exposures of pre-Recent sediments along the coast of this area are the Upper Cretaceous sandstones, limestone, and conglomerates (Chico) on the north side of Punta Banda, the sandstone and conglomerate formation (Trabuco ?) on the north Todos Santos Island and Punta Banda, and the Upper Miocene (Comondú) agglomerates, tuffs, and sandstones along the north shore of the mainland.

There is no continuous supply of sediment being brought into the bay by freshwater drainage at the present time. Streams flow into the bay at El Sauzal, Ensenada, and the mouth of the Estero de Punta Banda and into the estero along the base of Punta Banda. The rivers at El Sauzal and Ensenada flow intermittently all year, but the other stream valleys are dry except during the rainy season. During the winter months occasional heavy rains flood the usually dry stream beds and contribute considerable sediment to the bay.

The stream at El Sauzal drains the area of Cretaceous and pre-Cretaceous crystallines of the mountains to the north and flows several miles through the agglomerates, tuffs, sandstones, and volcanics of the Comondú formation. The rivers flowing into the bay from the east also originate in the Cretaceous and pre-Cretaceous rocks of the mountains but flow through extensive areas of Quaternary alluvium. The erosion of the crystallines of Punta Banda undoubtedly contributes considerable sediment to the estero, as can be seen from the freshly-eroded appearance of the coarse brown sands near its head.

DISCUSSION

The sediments of Group II in the inner part of the bay appear to be derived from the normal processes of stream erosion of the highlands and the extensive deposits of alluvium lying to the north and east of the bay. The present supply of sediments does not appear to be very great, and it is possible that some of the Group II sediments were derived from a previous cycle of heavier rainfall and subsequently distributed by marine processes.

The sediments of Group III appear to be the normal seaward extension of the Group II sediments. There is a decrease in grain size, they become more poorly sorted, and there is an increased skewness toward the finer sizes offshore; these factors are gradational between the two groups. The boundary between these groups is not sharp and is of necessity generalized, but it corresponds approximately with the 100-fathom contour.

Emery (1952) has recognized several types of sediments off the coast of southern California. Emery states (op. cit., p. 1107):

> "When sediments of authigenic, organic, residual, and relict origin are recognized and only the remaining detrital sediments are considered, the detrital sediments present a general trend of decreasing grain size in a seaward direction for the shelf off southern California."

He has recognized sediments similar to the present Group I sediments from Santa Monica Bay, San Pedro Bay, and off San Diego. A detailed study of the sediments off San Diego (Emery, Butcher, Gould, & Shepard, 1952) points out the complex sediment distributions that are encountered as a result of the mixing of sediment types other than detrital.

The characteristics of the Group I sediments, their geographic and bathymetric position, and the relationship to the other sedimentary groups indicate that they are not in adjustment with the present environment. The faunal data presented in a later section substantiate this conclusion.

The largest area of Group I sediments from the Todos Santos Islands to the mainland on the north side of the bay is complex and difficult to explain in terms of the present environment. The depth of water in which they occur, the presence of glauconite, the abundant organic remains, the presence of pebbles and cobbles encrusted with living

organisms, and their geographic position suggest a source or sources other than those supplying sediment to the area at the present time. As with the other boundaries, there is no sharp contact between this group and the adjacent groups. The transition on the bay side is gradual with no apparent change in topography except to the east and south of the south Todos Santos Island, where the narrow insular shelf terminates in the steep walls of the deep channel. The presence of well-rounded pebbles and cobbles over most of this area suggests that it was, at some time in the past, subjected to the rigorous environment of the surf zone. There are no known physical agencies in the area at the present time that could account for such well-rounded pebbles and cobbles at the depth in which they occur. Also, the presence of living encrusting organisms on the pebbles and cobbles indicate that they are not at present undergoing any appreciable transportation or abrasion. The extremely high populations of dead Foraminifera and the presence of glauconite over the area suggest slow deposition.

It appears that this sediment is at least in part a result of vigorous abrasion by wave action at a time of lowered sea level. There are several possible sources of these sediments. The north Todos Santos Island is covered by a thick wedge of sandstones and conglomerates, and at least part of the bay area near El Sauzal is covered by submarine outcrops of a coarse brown sandstone. Subaerial and submarine weathering of these older sediments has undoubtedly contributed much of the coarse, sandy sediment found in the area. The well-rounded pebbles and cobbles of tuffs and agglomerates evidently originated in the hills to the north of the area. The continuous accumulation of foraminiferal shells and the lack of dilution by sediments has resulted in the large dead populations of Foraminifera.

The occurrence of Group I sediments at the mouth of the estero apparently is a result of the scouring action of the strong tidal currents which flow in and out of the estero. The nearshore drift in this part of the bay is to the north and it is suggested that the strong tidal currents, which reach velocities up to 2 knots, keep the area in the immediate vicinity of station B-73 free of finer sediments.

The sediments along Punta Banda reflect the influence of the poorly-consolidated Cretaceous sandstones which form precipitous cliffs along Punta Banda. The narrow beaches at the foot of the cliffs are littered with material that has been eroded back by an encroaching sea leaving a residual sediment near shore. There is no sharp contact or topographic change between these sediments and the adjacent Group II sediments. These sediments along Punta Banda apparently result from subaerial and possibly submarine erosion of the Cretaceous strata.

The importance of recognizing these relict or residual sediments cannot be over-emphasized. The presence of such sediments on the continental shelf, particularly off southern California and Mexico, indicates that large areas of the shelf are not in equilibrium with the present environmental conditions. The geological importance of such sediment types in the reconstruction of ancient environments is obvious. They must be recognized and separated from normal sediment distributions in order to establish useful principles of distribution for Recent sediments.

In summary, the sediments of Todos Santos Bay appear to be the result of two different environments of deposition. Group I sediments constitute an "unconformable" surface which appears to be the result of a past lowering of sea level. Group II and Group III sediments, which grade offshore from fine sands to silts and clays, appear to reflect the present environments of deposition in which they are found. The sediments reflecting the present environments appear to be transgressively overlapping the older sediments of Group I; but due to the limited supply of new sediments to the area at the present time, they have not succeeded in masking the old erosion surface. (Faunal evidence of the preceding conclusions is given on following pages.) The contamination of the Recent sediments by subaerial and submarine outcrops of "fossil" sediments is well-demonstrated by the surface sediments near the Cretaceous strata along Punta Banda. The sediments of Group I are complex in origin and contain residual sediments from the reworking of older strata, relict sediments from a previous lowering of sea level, abundant organic remains from the steady accretion of fo-

raminiferal shells, and elements of Recent sediments. The recognition of residual, relict, and "fossil" sediments as "contaminants" of the "Recent" sediments is essential in establishing principles of distribution of sediments which reflect present environments.

BENTHONIC FORAMINIFERAL FAUNAS

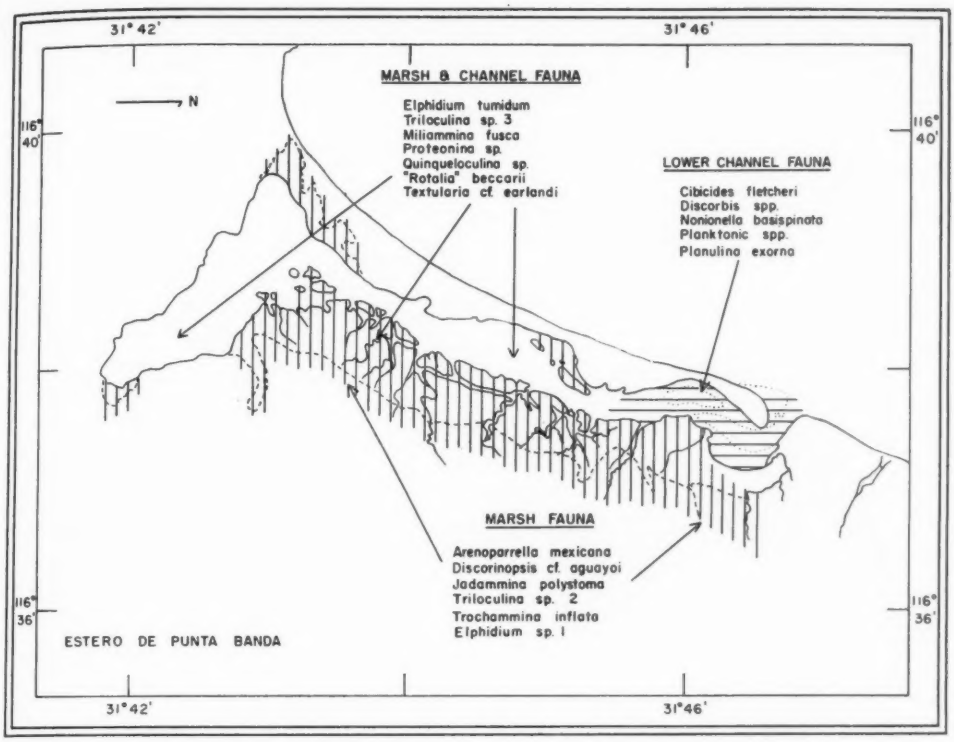
The benthonic Foraminifera of Todos Santos Bay can be divided into two well-defined groups: (1) the Estero de Punta Banda fauna and (2) the bay-open ocean fauna. These groups represent the two major environments of the area and reflect the differing physical, chemical, and biological controls of each environment. Each of these groups can be further divided into assemblages or "biofacies" within the two major environments.

ESTERO DE PUNTA BANDA FAUNA

The estero fauna consists of species which are restricted to a lagoon and marsh environment and also some species which

TABLE 6—OCCURRENCES OF LIVING AND TOTAL BENTHONIC FORAMINIFERA IN ACTUAL NUMBERS IN THE ESTERO DE PUNTA BANDA (PER UNIFORM SIZE SAMPLE).

LOCATION	MARSH													CHANNEL																								
STATION	E 4	E 7	E 10	E 11	E 14	E 15	E 16	E 26	E 27	E 28	E 29	E 30	E 31	E 1	E 2	E 3	E 5	E 6	E 8	E 9	E 12	E 13	E 17	E 18	E 19	E 20	E 21	E 22	E 23	E 24	E 25	E 32	E 33
DEPTH	I.T.	0'6"	I.T.	I.T.	I.T.	I.T.	I.T.	I.T.	I.T.	1'0"	I.T.	I.T.	I.T.	I.T.	I.T.	5'0"	6'6"	3'0"	2'0"	2'0"	2'0"	5'0"	6'0"	I.T.	5'0"	I.T.	5'0"	5'0"	1'0"	1'6"	1'0"	I'0"	F.T.
TOTAL LIVING POPULATION	0	40	40	108	10	4	0	0	26	30	0	0	0	14	20	6	12	108	6	0	8	20	0	0	104	0	0	0	0	2	0	0	64
Arenoparrella mexicana		2	4																														
Cibicides fletcheri														10																2			
Discorbis spp.														4							6												
Elphidium spinatum																																	
E. tumidum		2													14	6		44	4														63
E. sp. 1			4	4		4																											
Jadammina polystoma		6	6	10					2																								
Miliammina fusca				74						10					6		2	2			2	20											2
Proteonina sp.		30	26	20													10	42															
Quinqueloculina sp.																			2						2								
"Rotalia" beccarii																																	2
Triloculina sp. 2									4	20																							
T. sp. 3																									182								
Trochammina inflata					10				20																								
TOTAL DEAD POPULATION	20	84	80	140	108	10	18	28	288	178	2	40	134	16	36	81	28	158	30	62	34	62	3	0	215	22	33	6	36	10	96	6	140
Angulogerina angulosa																															6		
Arenoparrella mexicana		8	10		28	2							32						6	10					6								2
Buliminella bassendorfensis																						22			30		2		6		38		
Cibicides fletcheri														12	4											20	26	6	16	8	14		
Discorbis spp.														4							6				4		2		2		4		
Discorinopsis aguayoi	2							8		2																							
Elphidium spinatum																2																	
E. translucens																									10	2					4		
E. tumidum		2											12		24	46		80	8	28	6	8	2		30		1						76
E. sp.			4	20		4	2		68	2								10											6	2	5		
Jadammina polystoma	8	20	6	22			4	12	38			2	2							2													4
Lamellodiscorbis sp.																																	28
Miliammina fusca		16	24	74			2	2		36			66		6		2	2			14	20											10
Nonionella basispinata																									2		2		2		6		
Planulina exorna																															2		
Proteonina sp.		30	26	20													10	42															
Quinqueloculina sp.															2				2						12								
Reophax sp. 2						2										12	8	18	8	4	2	4									2		
"Rotalia" beccarii							2						6			8				8					2				4		14	2	4
Textularia cf. earlandi							2						2			10	8	6		2		8											2
Triloculina sp. 2									32	60		38																					
T. sp. 3																									118								
Trochammina inflata	10	8	10	4	80	2	6	6	218	12			14						6	8	6											4	22
Planktonic forms																3							1		1						1		



TEXT-FIG. 7—Foraminiferal faunas in the Estero de Punta Banda.

are most common in the bay environment. Undoubtedly, some of the latter are able to live in both environments whereas others appear to be contaminants from the bay. The distribution of the foraminiferal species is presented in Table 6. The distribution of the faunas in the Estero de Punta Banda is shown in Text-figure 7.

Marsh facies.—The species characteristic of the marsh facies are perhaps the most distinctive; the living representatives are restricted to the intertidal area covered by marsh grasses, *Salicornia pacifica* and *Spartina leiantha.*

The following species are representative of the inter-tidal areas of marsh grasses:

Arenoparrella mexicana (Kornfeld)
Discorinopsis cf. *D. aguayoi* (Bermudez)
Elphidium sp.
Jadammina polystoma Bartenstein and Brand
Triloculina sp. 2
Trochammina inflata (Montagu)

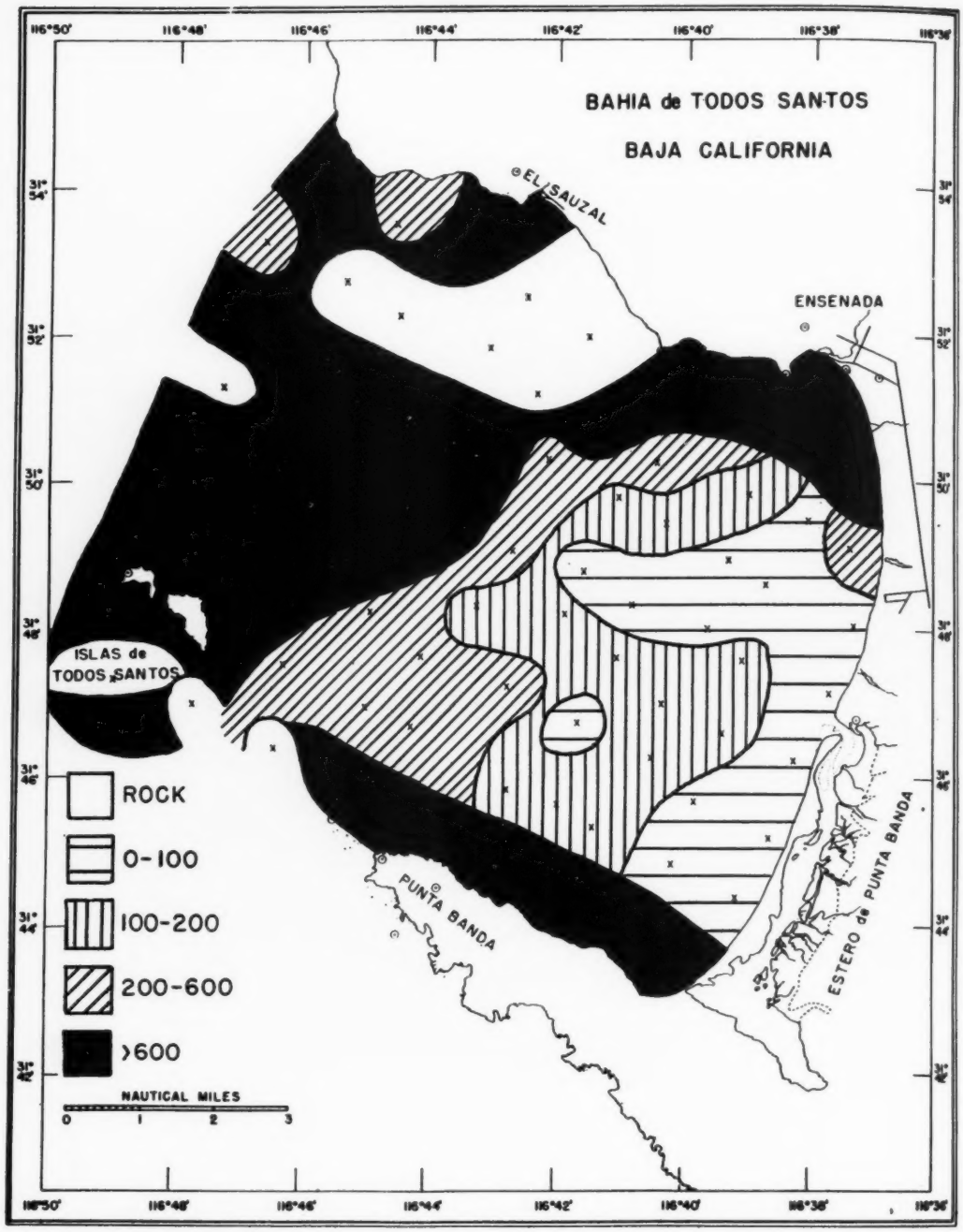
The distribution of the dead specimens of these species does not coincide with the living distributions in all cases. Dead specimens are common in the channels and on the inter-tidal sand flats.

Lower channel facies.—The lower channel fauna appears to reflect the influence of the bay environment. The species are common in the bay and some undoubtedly are contaminants from the bay. They only occur living at or near the mouth of the estero, in the channel, and on the inter-tidal sand flats. The lower channel fauna is characterized by the following species:

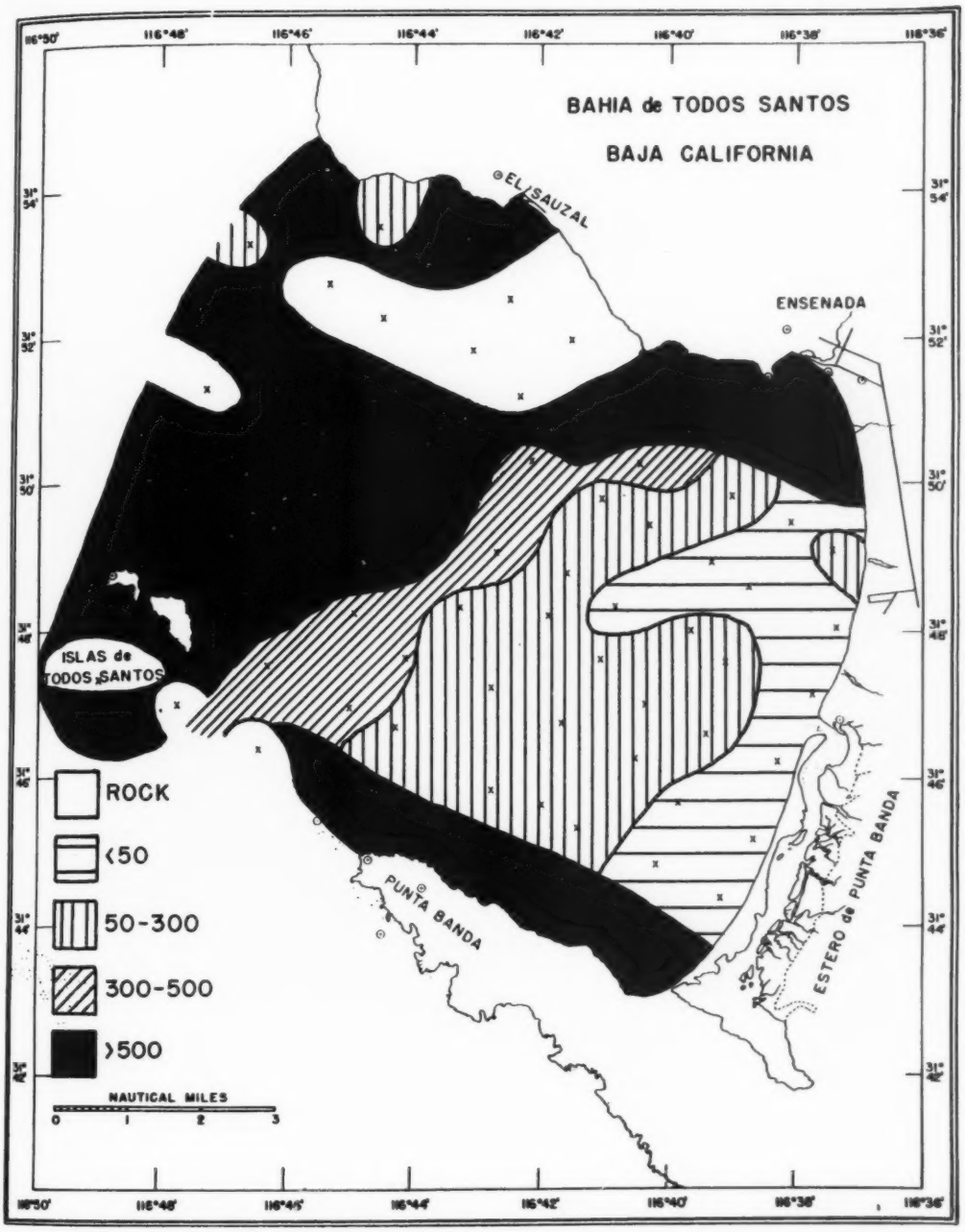
Cibicides fletcheri Galloway & Wissler
Discorbis spp.
Nonionella basispinata (Cushman & Moyer)

A few specimens of planktonic species are found in this fauna.

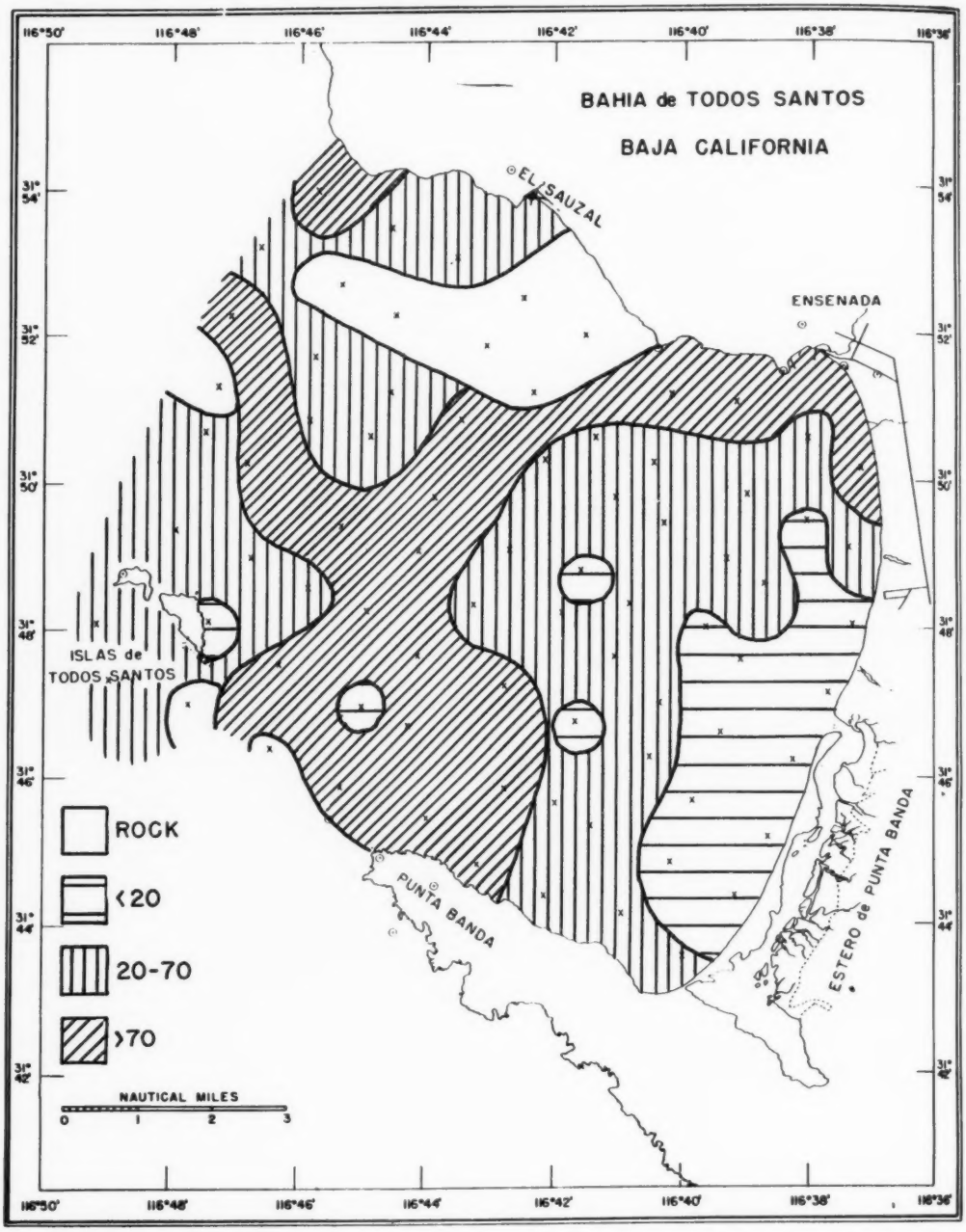
Mixed channel and marsh facies.—Some species are common both in the channels and inter-tidal flats and in the marsh areas. *Elphidium tumidum* Natland, *Miliammina fusca* (H. B. Brady), and *Proteonina* sp. occur in both of these environments. *Quinqueloculina* sp., *Triloculina* sp. 3, and "*Rotalia*" cf. "*R.*" *beccarii* (Linné) are found



TEXT-FIG. 8—Distribution of total (living and dead) populations of benthonic Foraminifera in Todos Santos Bay in number of specimens per sample.



TEXT-FIG. 9—Areal distribution of dead benthonic Foraminifera in Todos Santos Bay in number of specimens per sample.



TEXT-FIG. *10*—Areal distribution of living benthonic Foraminifera in Todos Santos Bay in number of specimens per sample.

living only in the channel and inter-tidal sand flat samples; the dead representatives of these species are not as restricted in their distribution as are the living specimens (Table 6). *Lamellodiscorbis* sp. was found at only one station in the estero (E-33). *Triloculina* sp. 3 was recorded only from Station E-19.

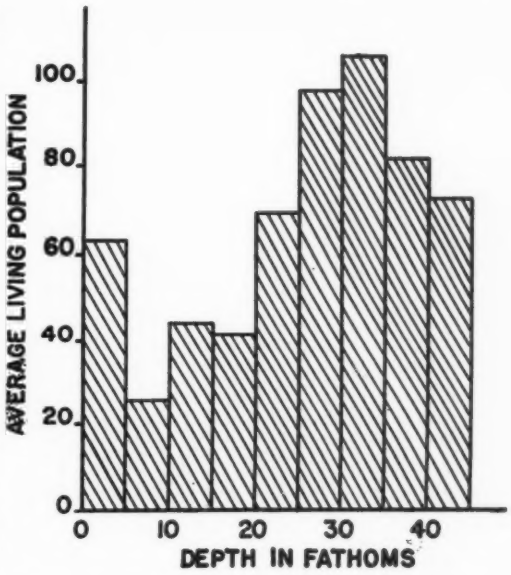
BAY FAUNA

Foraminiferal populations.—The distribution of total populations (living and dead) of benthonic Foraminifera in Todos Santos Bay is shown in Text-figure 8. The populations are small near the inside of the bay and generally increase with increasing depth. Unusually large populations occur along Punta Banda and between the Todos Santos Islands and the mainland to the northeast. The distributions of the dead populations (Text-fig. 9) are strikingly similar to the distributions of the total populations (living and dead). The living populations, however (Text-fig. 10), show different distributions from the dead and total populations. The frequency distribution of the average living populations per 5-fathom interval shows a marked maximum between 30 and 35 fathoms (Text-fig. 11). The frequency distribution of the dead populations per 5-fathom intervals is multimodal (Text-fig. 12). The high populations of dead Foraminifera do not correspond with the areas or depths of maximum production of living Foraminifera in the bay at the time of collection. A comparison of the variations in the total living and total dead populations shows striking differences. The total living populations vary between 0 and 229 specimens per sample. The total dead populations vary over the same area from 0 to more than 18,000 specimens per sample.

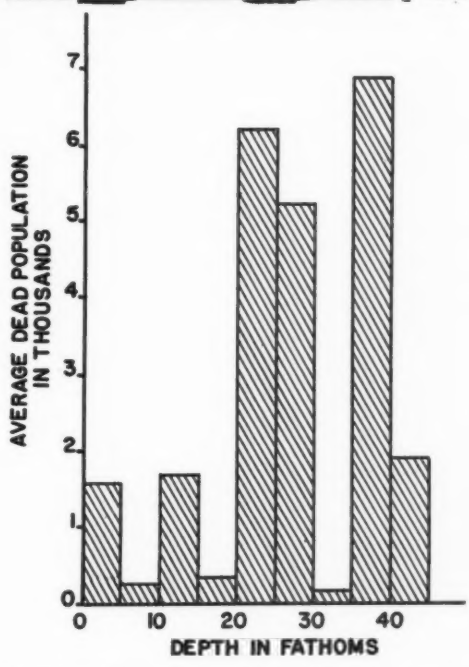
The sizes of populations of empty tests are primarily functions of: (1) rates of production of tests, (2) dilution of populations by detrital sediments, and (3) preservation of the empty tests.

In order to examine the relationship between the living and dead populations an "L/D" ratio has been established, as follows:

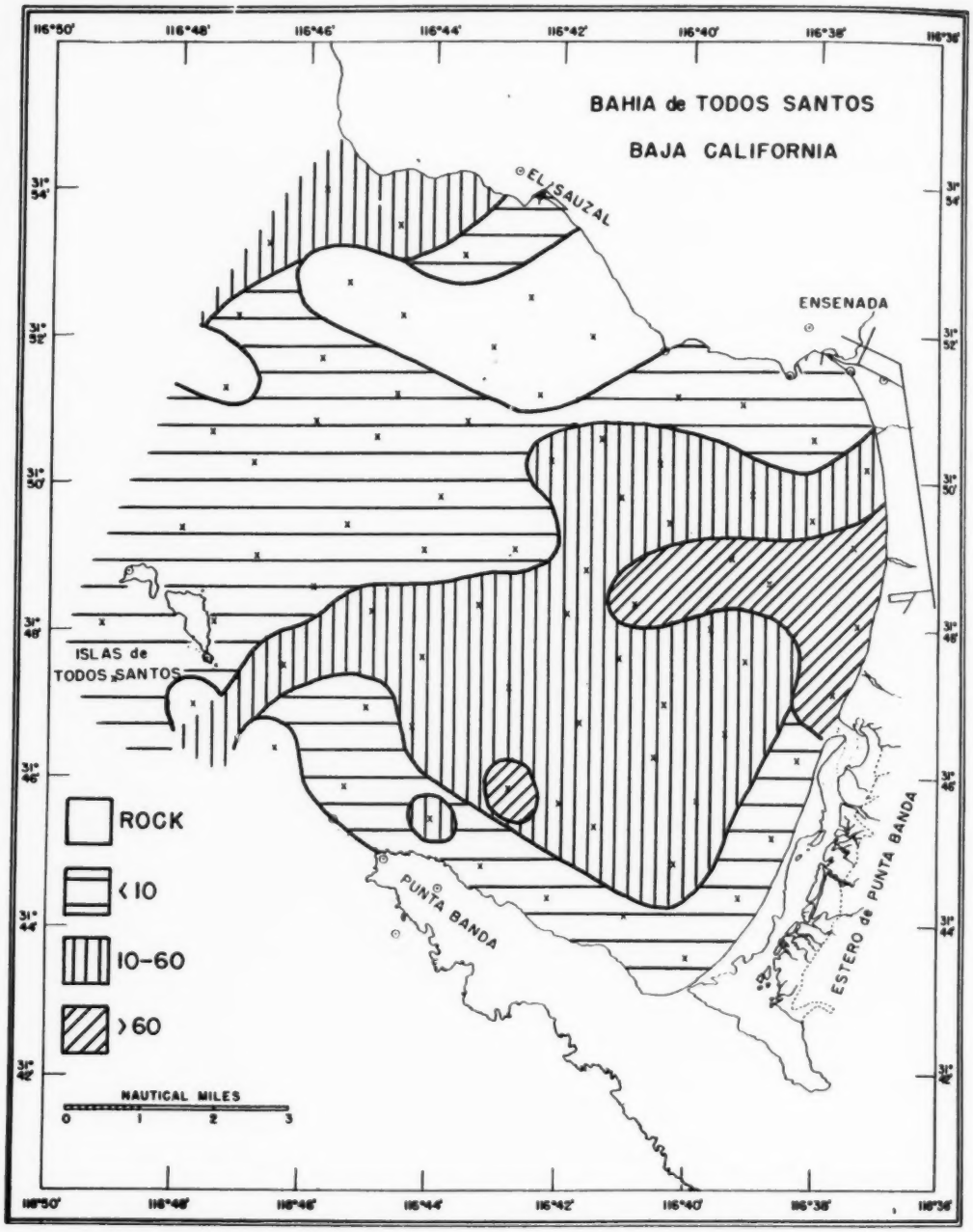
$$R = \frac{\text{living population}}{\text{dead population}} \times 100$$



TEXT-FIG. *11*—Depth distribution of average living populations of benthonic Foraminifera in Todos Santos Bay.



TEXT-FIG. *12*—Depth distribution of average dead populations of benthonic Foraminifera in Todos Santos Bay.



TEXT-FIG. *13*—Areal distribution of L/D ratios in Todos Santos Bay.

This ratio varies from less than 1 to more than 100 in Todos Santos Bay, as shown in Text-figure 13 and Table 7. A comparison of the areal plot of the L/D ratios (Text-fig. 13) with the total dead populations (Text-fig. 9) and the total living populations (Text-fig. 10) demonstrates that the L/D ratios vary according to dead populations and are less influenced by the relatively smaller variations in the living populations.

TABLE 7.—TOTAL LIVING AND DEAD POPULATIONS AND L/D RATIOS FOR TODOS SANTOS BAY SAMPLES

Sta. No.	Depth (fms.)	Living	Dead	L/D ×100
B-34	3	63	1,154	5.5
B-35	8	24	673	3.6
B-36	19	64	548	11.3
B-37	25	105	1,610	6.5
B-38	35	140	579	24.2
B-39	68	104	973	10.7
B-42	39	23	13,218	.2
B-43	40	46	12,520	.4
B-44	25	14	7,264	.2
B-45	141	98	506	19.4
B-46	150	16	256	6.3
B-47	108	80	215	37.2
B-48	30	91	82	111.0
B-49	28	44	73	60.0
B-50	20	65	162	40.1
B-51	12	1	4	25.0
B-52	6	—	—	—
B-53	7	—	—	—
B-54	11	5	19	26.3
B-55	18	63	121	52.0
B-56	24	13	55	23.6
B-57	31	121	257	47.1
B-58	96	144	382	37.6
B-59	110	88	413	21.3
B-60	110	42	892	4.7
B-61	92	40	1,087	3.7
B-62	23	52	771	6.8
B-63	22	61	11,632	.5
B-64	24	148	13,296	1.1
B-65	28	229	12,960	2.0
B-66	27	105	1,370	7.7
B-67	24	62	126	49.2
B-68	19	42	153	27.4
B-69	19	32	109	29.4
B-70	17	27	114	23.7
B-71	12	19	141	13.5
B-72	5	—	3	—
B-73	5	24	38	63.2
B-74	12	18	125	14.4
B-75	15	17	59	28.8
B-76	16	21	22	95.5
B-77	16	8	85	7.1
B-78	17	22	311	7.1
B-79	20	93	903	10.3
B-80	22	44	3,501	1.3
B-81	22	40	10,088	.4
B-83	26	124	12,936	1.0
B-84	22	66	18,592	.4
B-85	20	69	6,624	1.0
B-86	20	115	8,702	1.3
B-87	12	63	314	20.1
B-88	16	57	94	60.1
B-89	15	32	86	37.2
B-90	13	37	44	84.1
B-91	11	22	20	109.0
B-92	6	3	2	150.0
B-93	6	57	184	67.9
B-94	10	13	23	56.5
B-95	13	36	149	24.2
B-96	15	44	391	11.5
B-97	15	23	1,621	13.8
B-102	26	60	202	29.7
B-103	19	134	649	20.6
B-104	13	34	168	22.2
B-105	12	63	2,304	2.7
B-108	11	136	12,104	1.1
B-109	10	126	6,632	1.9
B-110	8	45	569	7.9
B-111	6	75	594	12.6
B-116	153	16	376	42.5
B-118	275	137	638	21.5

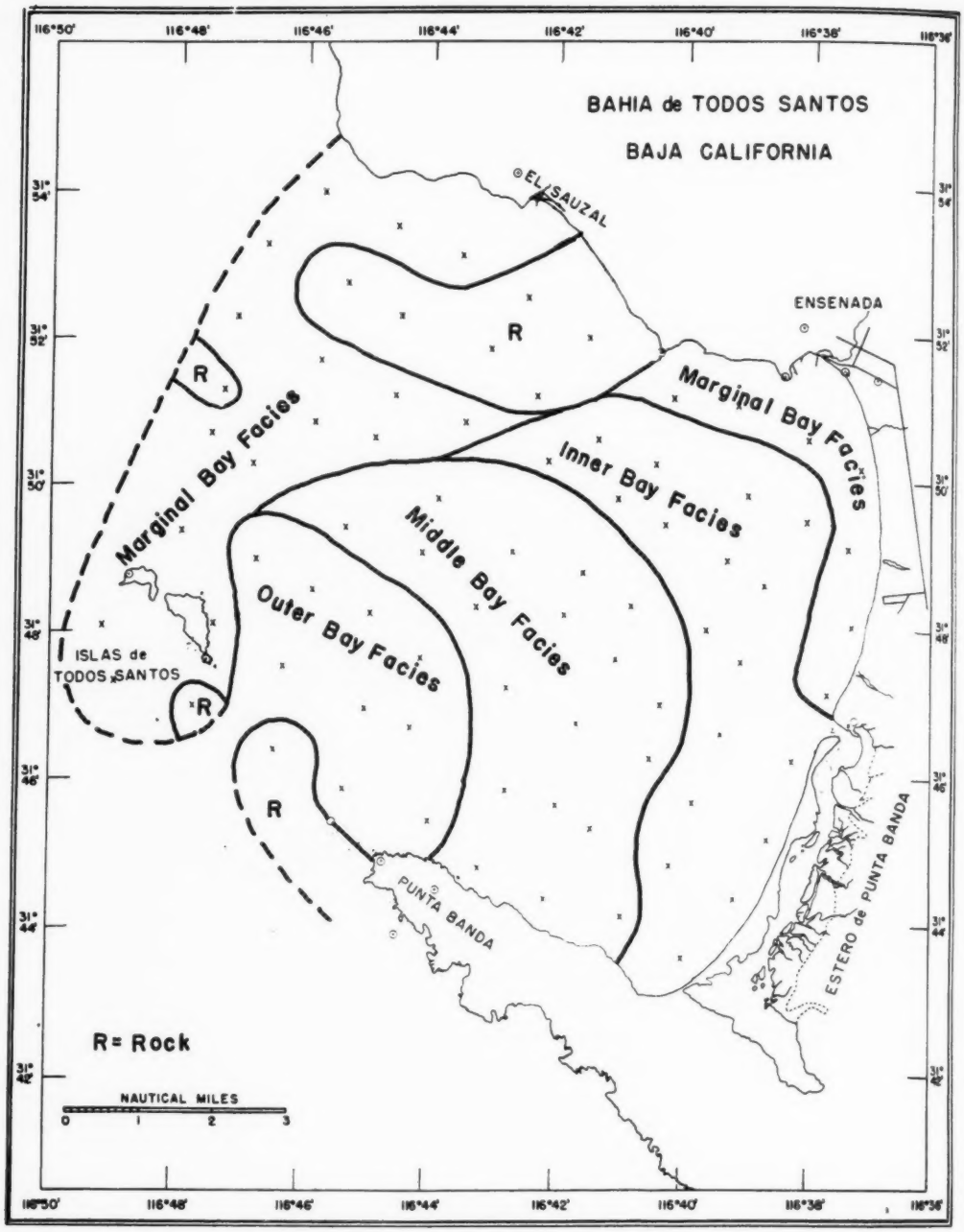
The living representatives of the benthonic foraminiferal species in Todos Santos Bay generally fit into four areal assemblages. The boundaries of these assemblages are generalized but the species associated with each assemblage occur most abundantly within the areas outlined in Text-figure 14.

Outer bay facies.—The following group of species is restricted to the deeper part of the bay and the deep channel between Punta Banda and the Todos Santos Islands:

Reophax gracilis (Kiaer)
Uvigerina peregrina Cushman vars.
Recurvoides spp.
Chilostomella ovoidea Reuss
Bolivina acuminata Natland
B. pacifica Cushman & McCulloch
Bulimina denudata Cushman & Parker
Globobulimina spp.

Middle bay facies.—A second assemblage has an areal distribution generally marginal to the deep depression in the center of the bay. The species are:

Goësella flintii Cushman
Reophax curtus Cushman
Proteonina sp.
Ammotium planissimum (Cushman)
Labrospira cf. *L. advena* (Cushman)
Reophax scorpiurus Montfort



TEXT-FIG. *14*—Benthonic Foraminiferal facies in Todos Santos Bay.

Inner bay facies.—A third group of species is most abundant in the inner part of the bay, but generally occurs over the entire bay area. The group includes the following species:

Nonionella miocenica stella Cushman & Moyer
Proteonina atlantica Cushman
Nonionella basispinata (Cushman & Moyer)
Discorbis spp.
Labrospira cf. *L. columbiensis* (Cushman)
Trochammina pacifica Cushman
Eggerella advena (Cushman)
Quinqueloculina sp.
Elphidium translucens Natland
Buliminella elegantissima (d'Orbigny)

Marginal bay facies.—The species of this assemblage generally are distributed over the area of relatively shallow water between the islands and the mainland on the northeast, and the areas immediately adjacent to the mainland and Punta Banda. This group includes the following species:

Angulogerina angulosa (Williamson)
Cassidulina subglobosa H. B. Brady
Cibicides fletcheri Galloway & Wissler
Cibicidina nitidula Bandy
Elphidium tumidum Natland
"*Rotalia*" spp.
Bolivina striatella Cushman
Textularia cf. *T. schenchi* Cushman & Valentine
Gaudryina cf. *G. subglabrata* Cushman & McCulloch
Bolivina vaughani Natland
Bifarina hancocki Cushman & McCulloch
Planulina exorna Phleger & Parker

Several species of Foraminifera were identified from Todos Santos Bay for which no living representatives were found. These are the following:

Elphidium crispum (Linné)
Eponides cf. *E. repandus* (Fichtel & Moll)
Astrononion stellatum (Cushman & Edwards)
Rudigaudryina inepta Cushman & McCulloch
Rupertia cf. *R. stabilis* Wallich
Bolivina cf. *B. pseudoplicata* Heron-Allen & Earland
Cassidulina californica Cushman & Hughes
Sigmoilina cf. *S. miocenica* Cushman
Various Miliolidae

FORAMINIFERAL ASSEMBLAGES IN OFFSHORE TRAVERSE

Composition of the offshore fauna.—The benthonic foraminiferal faunas of the offshore traverse belong to the bay-open ocean fauna. This assemblage generally occurs outside the immediate area of Todos Santos Bay and extends to depths of at least 600 fathoms. It is characterized by the following species:

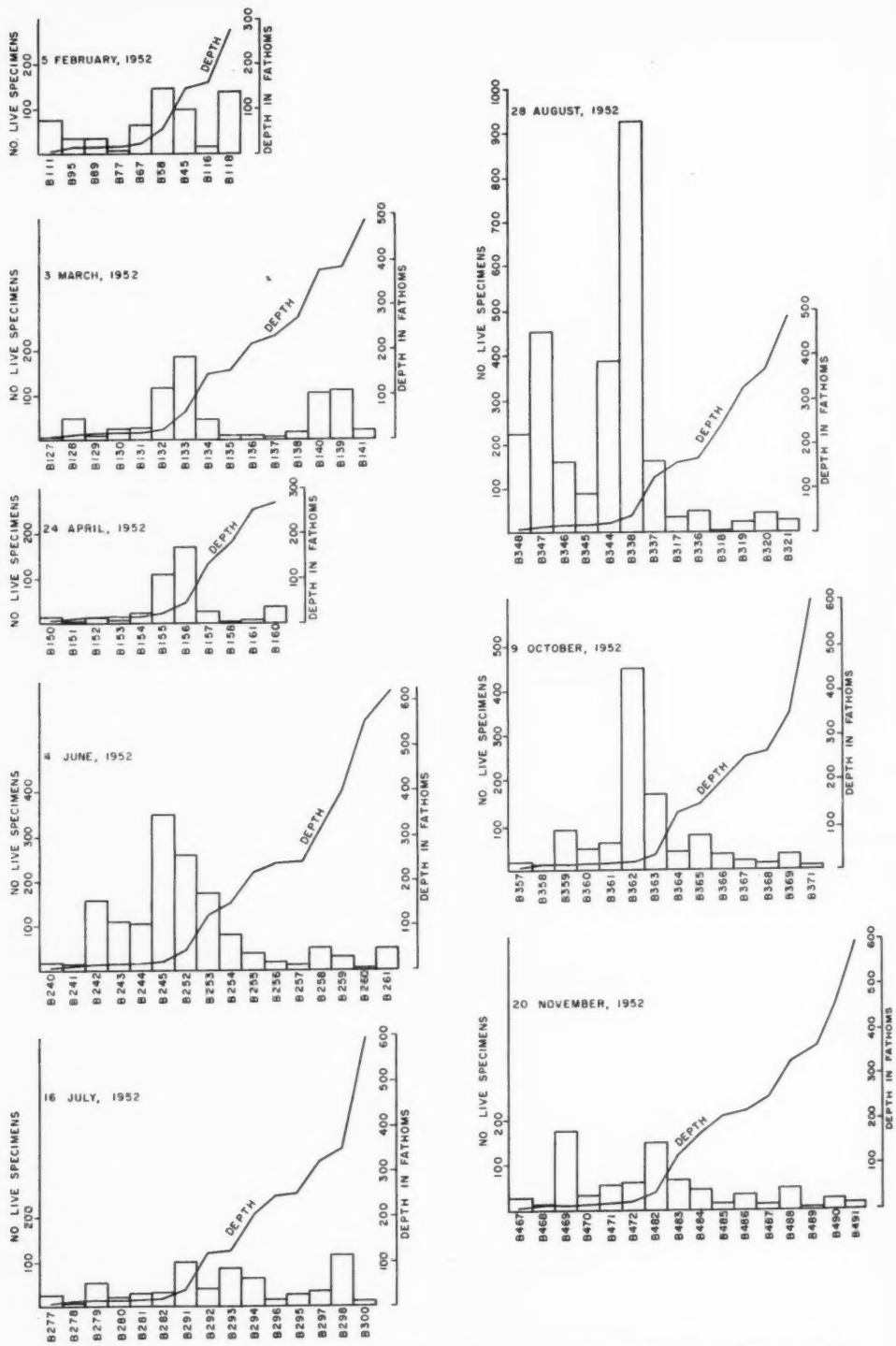
Cancris auricula (Fichtel & Moll)
Valvulineria araucana (d'Orbigny)
V. inequalis (d'Orbigny)
Bolivina argentea Cushman
B. spissa Cushman
B. minuta Natland
Cassidulina delicata Cushman
C. laevigata d'Orbigny
Bulimina exilis tenuata (Cushman)
Virgulina bramletti Galloway & Morrey
V. seminuda Natland
Reophax horrida Cushman
R. sp. 1
Proteonina sp.
Epistominella smithi (Stewart & Stewart)
Loxostomum pseudobeyrichi (Cushman)
Höglundina elegans (d'Orbigny)

As in the bay, the dead populations of the above species differ from the living ones in size and distribution. The dead specimens generally are much more common and occur through a greater depth range than the live specimens.

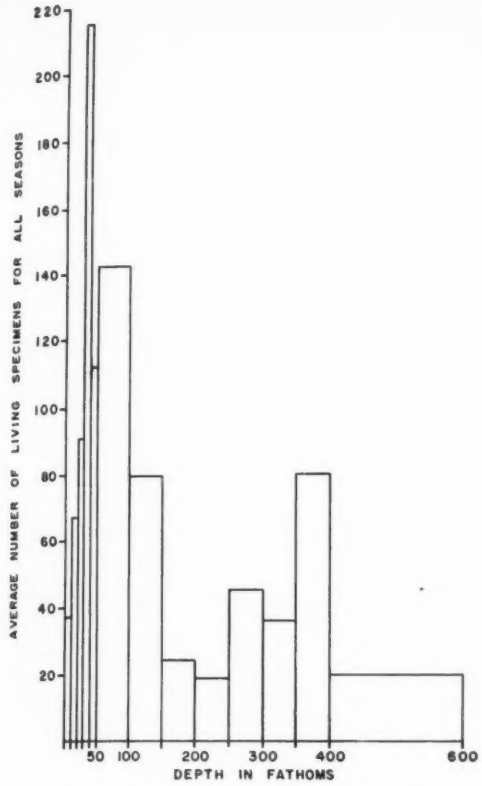
Living populations in seasonal samples.—Only living population counts were made from the seasonal samples. Histograms of the total living populations at each station for the eight seasonal collections are presented in Text-figure 15. A depth curve is plotted with each histogram for comparative purposes.

The seasonal histograms show two distinct variations in the living populations, a depth variation along the traverse and a seasonal variation. The average number of living specimens in all samples plotted against depth shows three distinct maxima (Text-fig. 16). The first maximum is at 30 to 40 fathoms. This is the most marked of the three maxima and the living populations average more than 200 specimens per sample at this depth. The second maximum occurs at 50 to 100 fathoms, and the samples have an average living population of 142 specimens. The third maximum occurs between 350 and 400 fathoms and averages 80 specimens per sample. It must be emphasized that this histogram of average living populations (Text-fig. 16) includes population counts from all seasons of the year and thus is influenced by seasonal variations.

Seasonal variations in living populations also are apparent in the seasonal traverse histograms (Text-fig. 15). The largest living



TEXT-FIG. *15*—Frequencies of living populations along seasonal traverses (per sample).



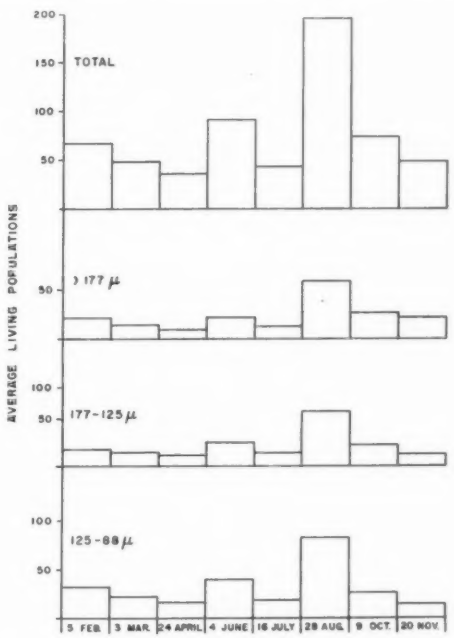
TEXT-FIG. *16*—Depth distribution of average living populations.

populations occurred in the August sampling with a smaller maximum in June. Seasonal variation is well-illustrated by a plot of the average living populations for each of the eight periods of collection (Text-fig. 17). This same illustration shows the relative abundances of living Foraminifera in the three size fractions from which population counts were made, with no appreciable differences in populations within different size fractions. Slightly larger populations occurred in the 125μ–88μ fraction at all seasons sampled except November. In November, the largest population occurred in the 177μ fraction.

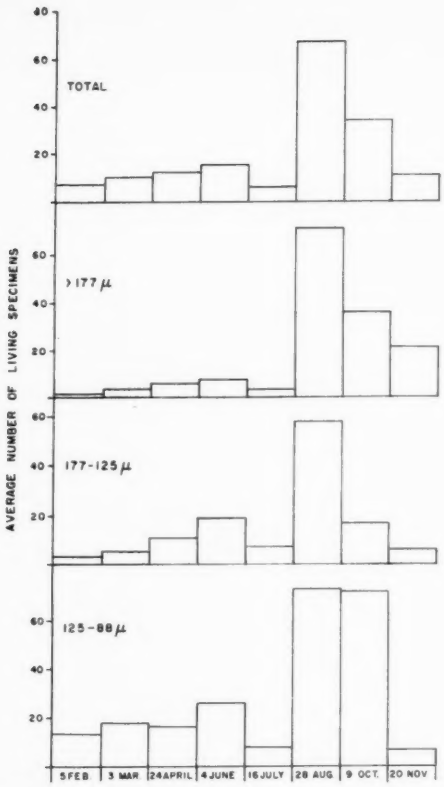
The seasonal variations in populations of individual species will affect the maximum and minimum populations shown in Text-figure 17. Seasonal distribution of *Nonionella miocenica stella* Cushman & Moyer in the total samples, and also the size fractions is shown in Text-figure 18. In this species there is also no appreciable difference in the size fraction populations, with slightly larger populations occurring in the 125–88μ fraction. This species was most abundant during August and is partly responsible for the maximum during that month. Other species show maxima during other seasons and contribute to fluctuations in the seasonal populations.

It is apparent that August is the month of maximum abundance of benthonic Foraminifera in this area. It also appears that each species has a discrete range over which it occurs. The frequency distributions of most of the species are represented in Text-figures 19–23.

Some species have very restricted depth ranges. *Quinqueloculina* sp., *Elphidium spinatum* Cushman & Valentine, *Miliammina fusca* (H. B. Brady), and *Textularia* cf. *T. earlandi* Parker (Text-figs. 19, 20) only occur over a depth range of 20 fathoms. *Elphidium translucens* Natland, *E. tumidum* Natland, *Gaudryina* cf. *G. subglabrata* Cushman & McCulloch, *Cibicidina nitidula* Bandy, and *Trochammina kellettae* Thal-



TEXT-FIG. *17*—Seasonal abundances of average living populations for total samples and size fractions.



TEXT-FIG. *18*—Seasonal abundance of *Nonionella miocenica stella* Cushman & Moyer; total samples and size fractions.

mann, etc. (Text-fig. 19) only occur over a depth range of 30 fathoms. These species, which have restricted depth ranges, all occur in water shallower than 40 fathoms.

A few species which are most abundant in water depths shallower than 50 fathoms apparently live over large depth ranges. *Labrospira* cf. *L. columbiensis* (Cushman) (Text-fig. 19) is most abundant shoaler than 50 fathoms but occurs to depths of 300 fathoms. *Goësella flintii* Cushman (Text-fig. 21) is most abundant between 40 and 50 fathoms, but occurs in depths of as much as 400 fathoms. Species which have frequency maxima shallower than 50 fathoms have fairly narrow depth ranges and are more skewed toward deep water. In contrast, species which have frequency maxima deeper than 100 fathoms have relatively wide depth ranges, but nevertheless tend to be skewed toward the deeper water.

Some of the frequency distributions show bimodal tendencies, as *Ammotium planissimum* (Cushman) (Text-fig. 21) and *Proteonina* sp. (Text-fig. 23). This fact suggests the possibility that more than one species was included in such plots.

Several species show patchy distributions. This tendency is most noticeable in forms that show a frequency maximum shallower than 50 fathoms and appears to be related to displacement of these shallow-water species into deeper water. Most of these anomalous occurrences are at or near the base of rugged submarine topography and appear to be displaced down slope along with shallow-water sediments. It is interesting to note that these shallow-water species are able to survive, possibly only temporarily, in deeper-water environments.

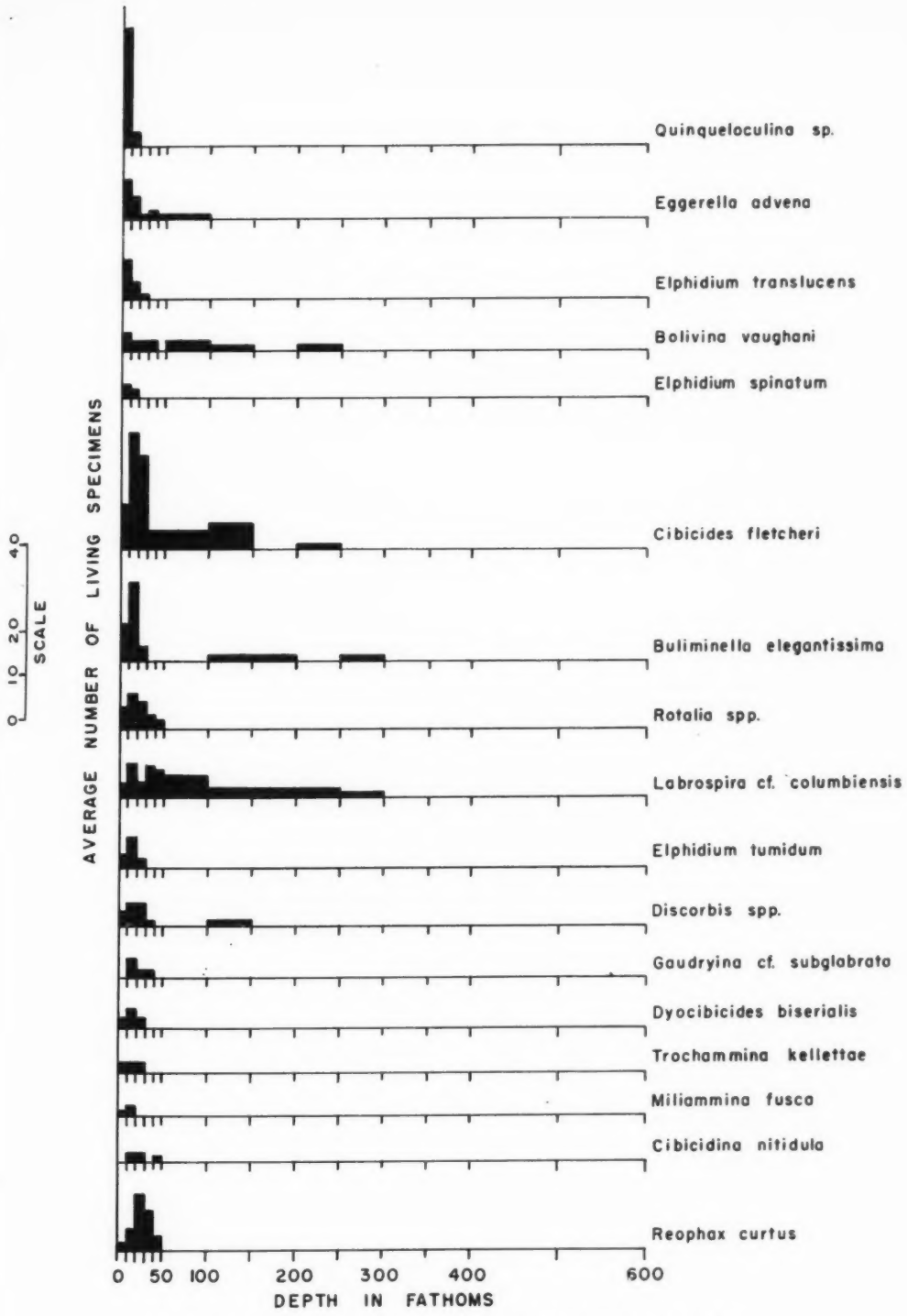
DEPTH FACIES

Four depth facies are recognizable within the bay and open-ocean fauna on the basis of the frequency distributions of living benthonic Foraminifera. These facies are bounded by distinct faunal boundaries and can be recognized easily from Text-figures 19–23. The upper boundary is at approximately 30 fathoms. Living specimens of the following species are restricted to depths of less than 30 fathoms:

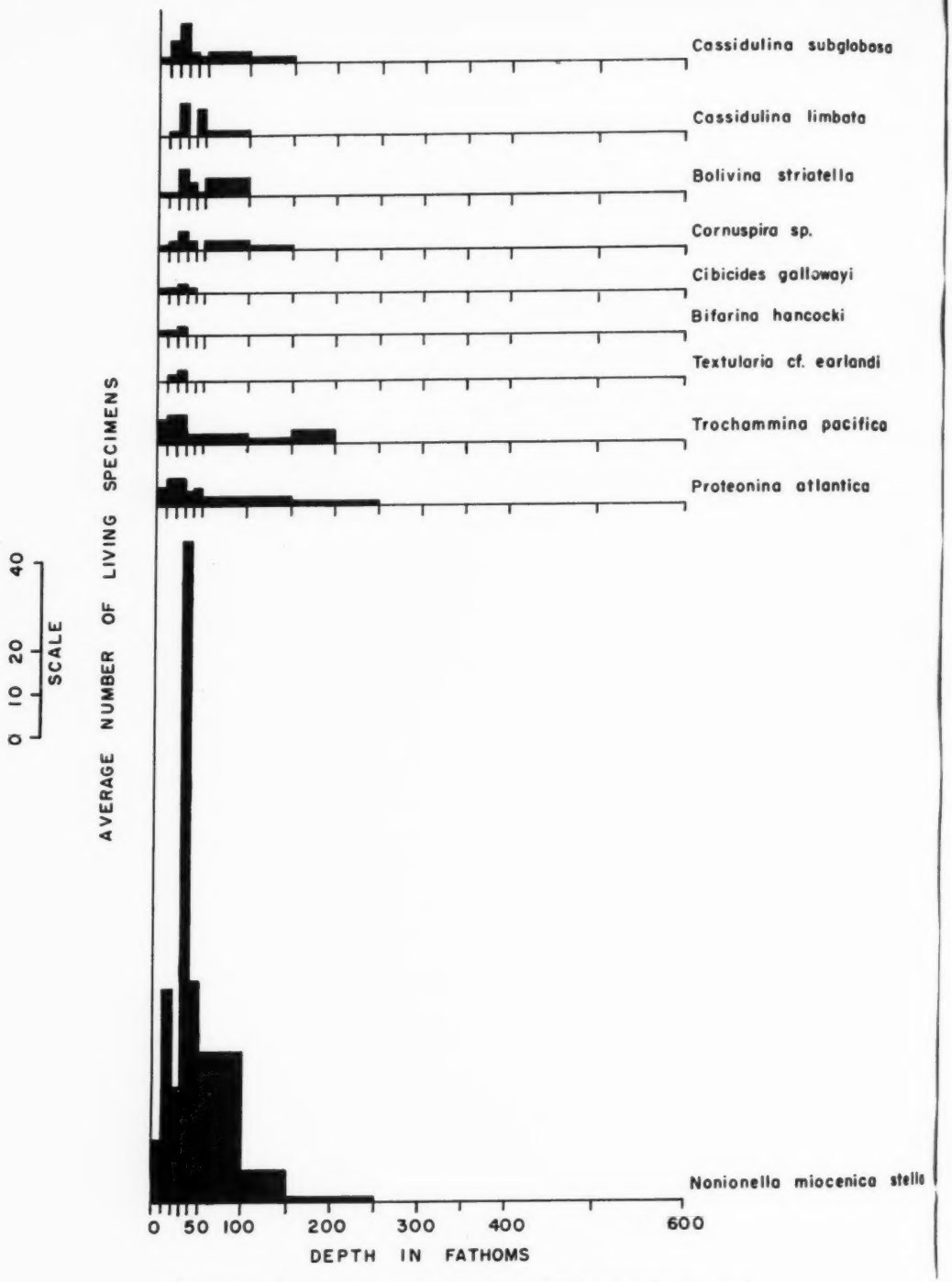
Quinqueloculina sp.
Elphidium translucens Natland
E. tumidum Natland
E. spinatum Cushman & Valentine
Dyocibicides biseralis Cushman & Valentine
Trochammina kellettae Thalmann
Miliammina fusca (H. B. Brady)
Bifarina hancocki Cushman & McCulloch
Textularia cf. *T. earlandi* Parker

The following species are most abundant above 30 fathoms but occur deeper:

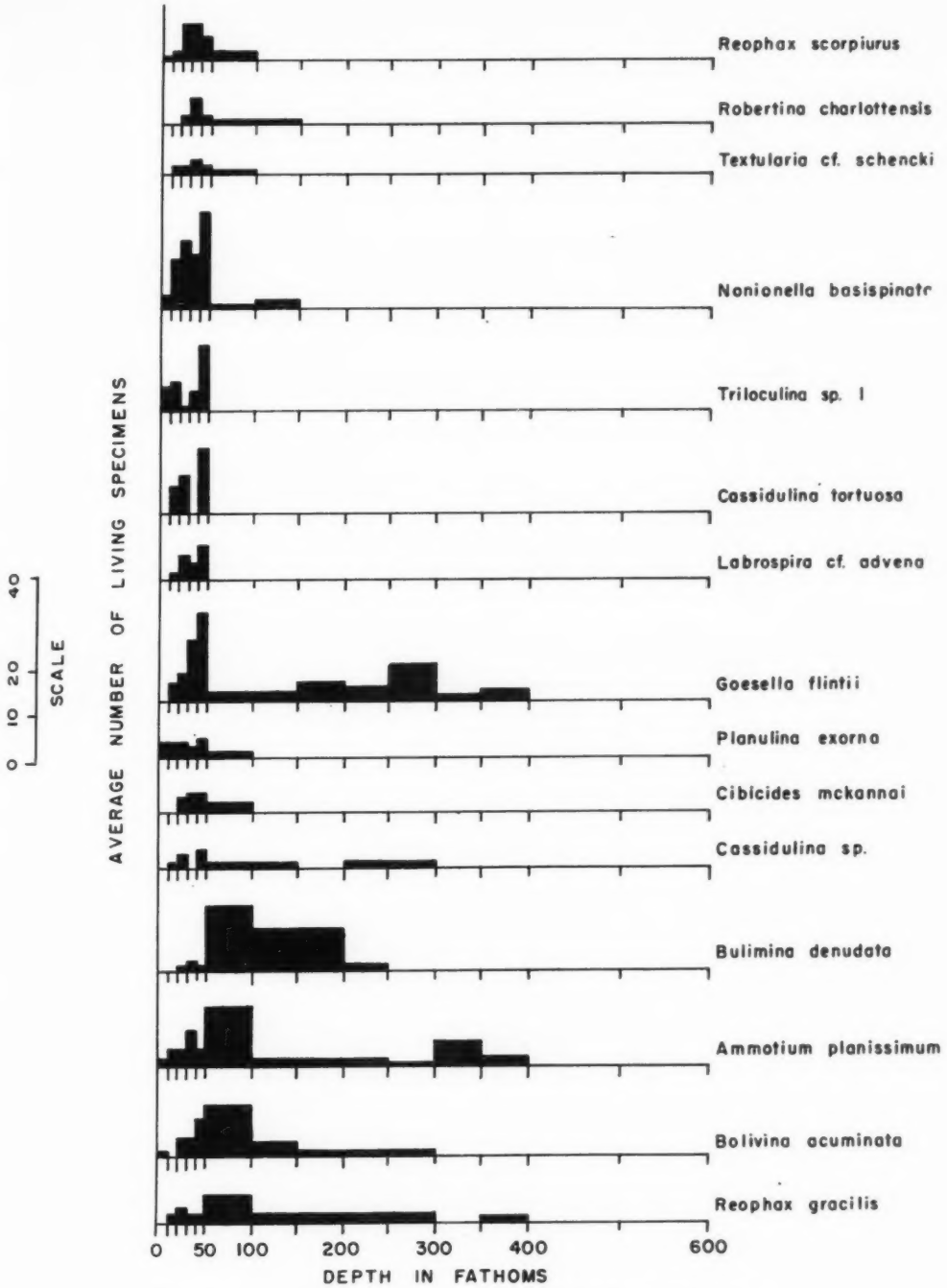
Eggerella advena (Cushman)
Bolivina vaughani Natland
Cibicides fletcheri Galloway & Wissler
Buliminella elegantissima (d'Orbigny)
"*Rotalia*" spp.
Labrospira cf. *L. columbiensis* (Cushman)
Discorbis spp.
Gaudryina cf. *G. subglabrata* Cushman & McCulloch
Reophax curtus Cushman
Cibicidina nitidula Bandy
Cassidulina subglobosa (H. B. Brady)
C. limbata Cushman & Hughes
Bolivina striatella Cushman
Cornuspira sp.
Cibicides gallowayi Cushman & Valentine
Trochammina pacifica Cushman
Proteonina atlantica Cushman



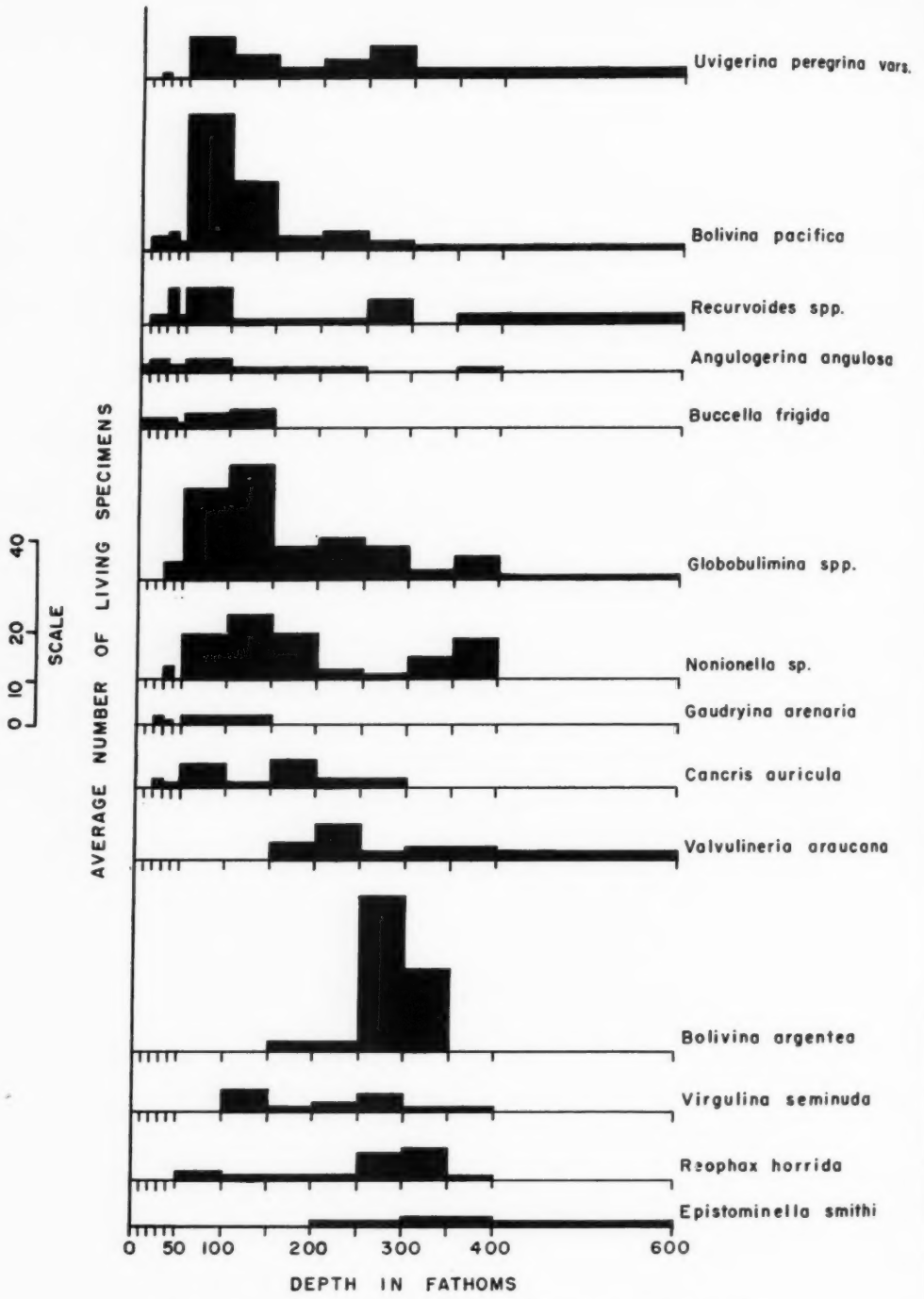
TEXT-FIG. *19*—Frequency distributions of living benthonic species.



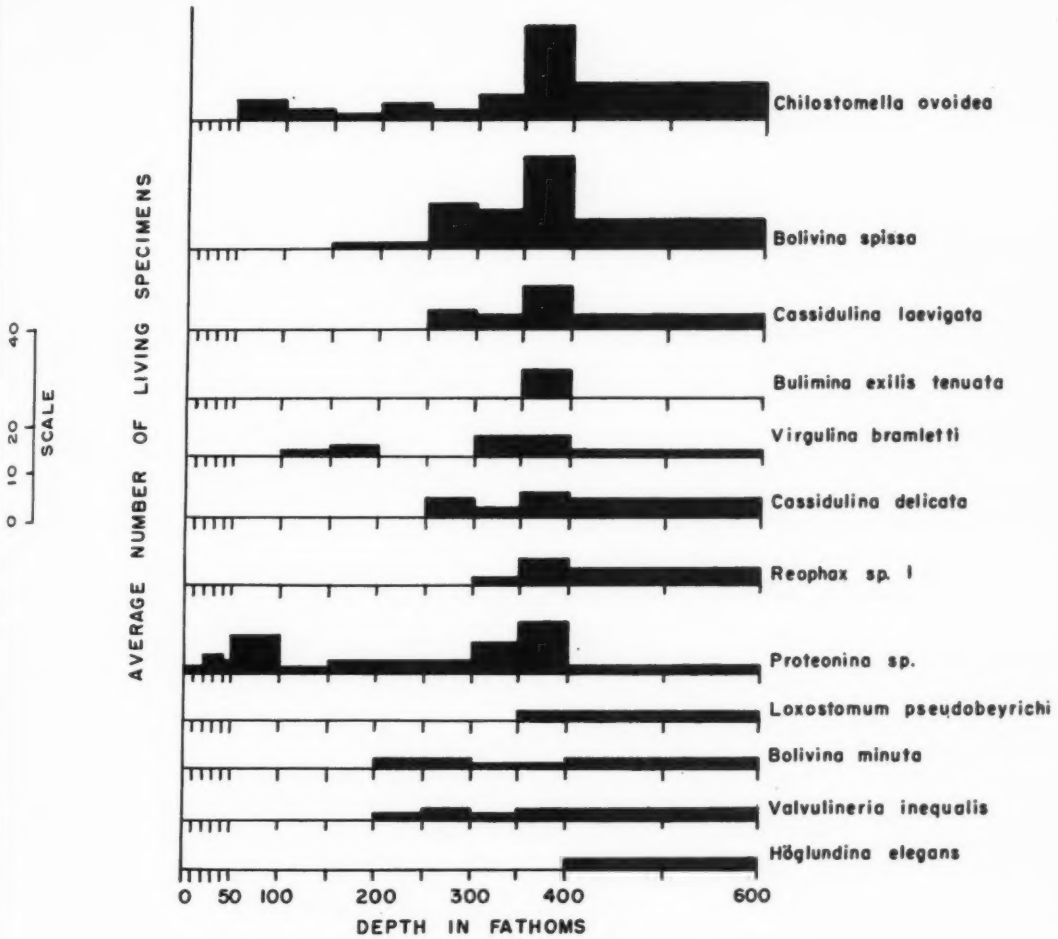
TEXT-FIG. *20*—Frequency distributions of living benthonic species.



TEXT-FIG. *21*—Frequency distributions of living benthonic species.



TEXT-FIG. *22*—Frequency distributions of living benthonic species.



TEXT-FIG. *23*—Frequency distributions of living benthonic species.

The second faunal boundary occurs at approximately 50 fathoms. No species are limited to 30–50 fathoms, but the following group occurs most abundantly within this range:

Nonionella miocenica stella Cushman & Moyer
Reophax scorpiurus Montfort
Robertina charlottensis (Cushman)
Textulara cf. *T. schencki* Cushman & Valentine
Nonionella basispinata (Cushman & Moyer)
Triloculina sp. 1
Cassidulina tortuosa Cushman & Hughes
Labrospira cf. *L. advena* (Cushman)
Goësella flintii Cushman
Planulina exorna Phleger & Parker
Cibicides mckannai Galloway & Wissler
Cassidulina sp.

The following species do not occur deeper than 50 fathoms:

"*Rotalia*" spp.
Reophax curtus Cushman
Triloculina sp. 1
Cassidulina tortuosa Cushman & Hughes
Labrospira cf. *L. advena* (Cushman)

The third faunal boundary occurs at approximately 100 fathoms. No species are restricted to the depth range 50 to 100 fathoms, but it is characterized by a group of species whose frequency distributions have pronounced maxima within this depth range. These species range both into shallower and deeper water, but their frequency

distributions tend to be skewed more toward the deeper end of their ranges. The following species are most abundant at approximately 50–100 fathoms:

Bulimina denudata Cushman & Parker
Ammotium planissium (Cushman)
Bolivina acuminata Natland
Reophax gracilis (Kiaer)
Uvigerina peregrina Cushman vars. [part]
Bolivina pacifica Cushman & McCulloch
Recurvoides spp.
Globobulimina spp.
Nonionella sp. [part]
Angulogerina angulosa (Williamson)
Buccella frigida (Cushman)
Gaudryina arenaria Galloway & Wissler
Cancris auricula (Fichtel & Moll)

The following species do not occur deeper than 100 fathoms:

Planulina exorna Phleger & Parker
Cibicides mckannai Galloway & Wissler
Textularia cf. *T. schencki* Cushman & Valentine
Reophax scorpiurus Montfort
Bolivina striatella Cushman
Cassidulina limbata Cushman & Hughes
Eggerella advena (Cushman)

A fourth faunal boundary occurs at approximately 350–400 fathoms. The species occurring most abundantly between 100 and 350–400 fathoms are:

Valvulineria araucana (d'Orbigny)
Virgulina seminuda Natland
Reophax horrida Cushman
Bolivina argentea Cushman

Deeper than approximately 350 fathoms, a group of species appears in abundance, and these are characteristic of water greater than this depth. These are:

Chilostomella ovoidea Reuss
Bolivina spissa Cushman
B. minuta Natland
Cassidulina laevigata d'Orbigny
C. delicata Cushman
Bulimina exilis tenuata (Cushman)
Virgulina bramletti Galloway & Morrey
Reophax sp. 1
Proteonina sp. [part]
Loxostomum pseudobeyrichi (Cushman)
Valvulineria inaequalis (d'Orbigny)

Höglundina elegans (d'Orbigny) does not occur shoaler than 400 fathoms.

PLANKTONIC FORAMINIFERA

The planktonic populations were counted from three size fractions. The distribution of total populations of planktonic Foraminifera in Todos Santos Bay is shown in Textfigure 24. The largest planktonic populations correspond to the area of largest benthonic populations and, in general, with the distribution of sediment Group I. Two aspects of the distribution of planktonic Foraminifera are of interest: (1) the very large populations in certain areas of the bay, and (2) the wide distribution of planktonic species.

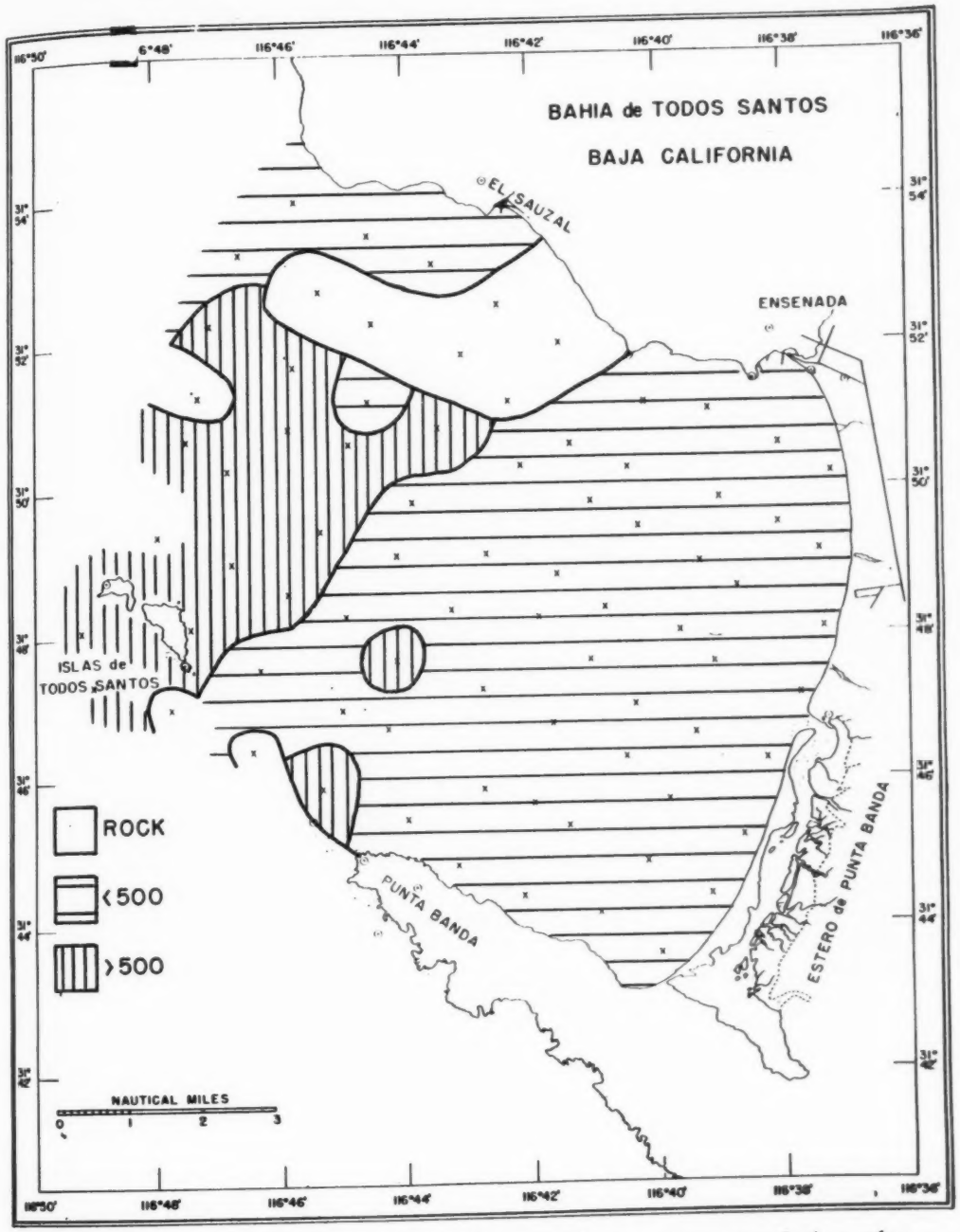
Dead planktonic Foraminifera have been found in practically all the samples examined. This wide distribution of planktonic forms and their occurrence in the Estero de Punta Banda demonstrates the apparent ease with which they are transported by currents. Phleger (1951b, p. 67) reports that planktonic Foraminifera are characteristic of offshore water masses and are seldom found in plankton tows in shoal areas. The very large planktonic populations from sediment samples in water depths less than 50 fathoms (exceeding 5,000 specimens per sample) do not appear to reflect the amount of productivity of planktonic species in the bay at the present time. Planktonic populations greater than 5,000 specimens (from comparable samples) are characteristic of water depths exceeding 1000 m. in the northwestern Gulf of Mexico (Phleger, 1951b, p. 67). These large planktonic populations appear to reflect the low rate of sedimentation in the area where they occur.

DISCUSSION OF RESULTS

COLLECTION OF SAMPLES

The stations from which sediment samples were collected in Todos Santos Bay are arranged in a one-mile grid pattern (Textfig. 2). In the descriptions of populations from samples collected over such a grid system, the assumption is made that the population of each sample is representative of a square mile of area. The sampling error in foraminiferal studies has never been determined accurately. Phleger (1952b) and Butcher (1951) report indirect evidence from the areal distributions of species of Foraminifera that their samples were representative. Their evidence is that individual species have reasonable distributions, reach maxima, and decrease in a regular manner away from centers of greatest abundance.

The density of samples necessary to repre-



TEXT-FIG. *24*—Areal distributions of planktonic Foraminifera in sediment samples in number of specimens per sample.

sent truly any variant depends upon its rate of variation. The variants measured in most foraminiferal studies are populations of the species. The rate of variation of foraminiferal populations per unit area is not the same for all species, as can be seen by a comparison of the distributions of the species in the Estero de Punta Banda with the deeper-water species in the open ocean. The rate of variation in the estero is extremely high, where populations of individual species may range from several hundred specimens to no specimens over a distance of a few feet or in some places a few inches. Large faunal variations in such environments necessitate closely-spaced samples. The open-ocean species, however, occur abundantly over depth ranges of hundreds of fathoms and distances of several miles, and samples in this environment may be spaced at greater distances and still adequately represent the populations.

The frequency distributions of living specimens of individual species in the open bay (Text-figs. 19–23) demonstrate that the populations of species occurring shallower than 50 fathoms have a higher rate of variation per unit area of sediment than do the populations deeper than 50 fathoms. This fact suggests that samples in the shoaler depths should be more closely spaced than offshore samples. In general, it appears that samples spaced closer than 1 mile apart in the bay are not necessary in order to represent accurately population variations of most foraminiferal species. The samples used in this study appear to give representative foraminiferal distributions.

It is necessary to maintain rigorous standards when collecting bottom samples for the study of living populations, and an attempt was made to eliminate as many sources of error as possible in the collection and preservation of the samples. The constant-volume sampler obtains a uniform volume of wet sediment from each sample. Immediate sampling of the cores in the field eliminated the possibility of disturbance of the samples during transit or storage.

The samples were preserved in neutral formalin at the time of collection to ensure preservation of the living Foraminifera. The use of formalin as a preservative necessitated periodic checks of the pH of the samples. Formalin decomposes with the formation of formic acid which lowers the pH of the samples. The rate at which the pH of a sample is lowered by the decomposition of formalin apparently varies with the amount of calcium carbonate in the sediment. The pH of clean, quartz sand samples, after being treated with neutralized formalin may drop below pH 7 within a few weeks. The pH of samples containing abundant remains of calcareous organisms may remain above 7 indefinitely without additional buffer.

EQUAL SAMPLES FOR COMPARATIVE PURPOSES

The problem of the type of sample from which quantitative counts of Foraminifera should be made has been given considerable attention in the literature. There appears to be two schools of thought concerning the problem of equal samples, one favoring population counts from samples of equal dry weight (Schott, 1935; Said, 1950) and the other from equal volume samples (Phleger, 1952b; Höglund, 1947; Parker, 1948; Butcher, 1951).

Most ecological work on modern Foraminifera is aimed at determining their distributions and relative abundances in modern sediments, which is a function of numerous and complex ecologic factors. Assuming that Foraminifera live at or just below the sediment-water interface, the natural measure of populations for comparative purposes should be the number of specimens per unit area. Assuming further that each environment is supporting the maximum number of Foraminifera possible, referring the population to any base other than available living space appears to be artificial. It is considered that wet volume of sediment is the only natural base to which living populations can be referred for comparative purposes.

It can be shown that the reference of benthonic foraminiferal populations to constant dry-weight samples may be misleading. The total living population at station B-111 in 6 fathoms is 75 specimens, the wet volume is approximately 10 cc., and the total dry weight is 13.8 grams. Station B-45 in 141 fathoms has a total living population of 102 specimens from a volume of 10 cc. of wet sediment, but the total dry weight of this

sample is 4.28 grams. These living populations are comparable when based on equal-volume samples, but based on equal dry weights the living population at station B-45 would be approximately 4 times as great as the population from sample B-111. This fact would suggest that at depths of 141 fathoms, the environment can support 4 times as many living Foraminifera as the shallow-water environment. Such conclusions are not valid in the light of what is known about the distribution of living Foraminifera.

If the sediment samples have been washed or otherwise concentrated before the dry weight is measured, the data are even less reliable. The weights just listed for samples B-45 and B-111 include the entire sediment sample. If only the coarser fractions of the samples are considered (sizes greater than $3\frac{1}{2}\ \phi$ or 0.088 mm.), which contain most of the Foraminifera, the dry weight of sample B-45 is 1.03 grams, and that of B-111 is 7.035 grams. It is obvious that population counts from dry, previously washed, or concentrated samples are not comparable and should not be considered representative.

SIGNIFICANCE OF SIZE STUDIES

The population counts were made from three size fractions and combined to get the total populations. Text-figure 17 illustrates the populations of the size fractions for the seasonal samples, and Text-figure 18 shows the fraction populations of the size fractions for *Nonionella miocenica stella*. These figures illustrate the relatively small differences in the populations of the size fractions. Only living populations are thus illustrated but the same relationship holds for the dead populations. The only generalization that can be made concerning the populations of the size fractions is that the largest populations occur in the finer size range between 125μ and 88μ in most samples. Even this generalization is variable, however, and depends upon the size of the dominant species at the place where the sample was collected. For example, station B-348 in 8 fathoms yielded a total population of 222 living specimens. Fifty-three specimens occurred in the coarse fraction, 54 specimens in the intermediate fraction, and 116 in the fine fraction. Approximately half of the total living population consists of three small species, *Bolivina vaughani*, *Buliminella elegantissima*, and *Eggerella advena*. Station B-132 in 52 fathoms yielded a living population of 117 specimens; 68 specimens occurred in the coarse fraction, 25 in the intermediate fraction, and 24 in the fine fraction. This population consists principally of *Ammotium planissimum*, *Goësella flintii*, *Proteonina atlantica*, and *Reophax scorpiurus*, all large forms.

ESTIMATION OF TOTAL POPULATIONS

The living populations presented in Tables 1–3 are actual counts from the entire samples, and most of the dead populations are actual counts; but it was necessary to estimate large dead populations by counting a fraction of the sample. This was done by splitting the sample, using the Otto Microsplit (Otto, 1933) and no population was estimated from a fraction smaller than $\frac{1}{16}$ of the total sample.

The number of specimens to be counted in any sample depends upon the accuracy desired, and, in general, the accuracy increases as the square root of the number of specimens counted. Ovey (1950, p. 213) shows that the error diminishes as the number of specimens counted increases. His data show that there is only a small error in a species forming 70–90% of the total population where 300 specimens were counted. Butcher (1951, p. 21) points out, however, that Ovey's "estimates of error are based on only two counts of the same sample and are not statistically sound." Ovey's conclusion, that population counts of less than 300 specimens may be unreliable, however, appears to be valid.

Dryden (1931, p. 236) shows that the accuracy of mineral grain counts increases very little after 300 or 400 grains have been counted. Population counts of mineral grains or Foraminifera of less than 300 specimens show marked increases in the per cent error in species forming small percentages of the population. It is apparent that the small increase in accuracy gained by counting more than 300 or 400 specimens in any sample does not justify the time involved, but conclusions drawn from population counts of less than approximately 300 specimens may not be reliable.

Dryden (op. cit.) discusses percentage representation of heavy mineral frequencies which also are applicable to foraminiferal counts. He recommends percentage representations but objects to the presentation of percentages that indicate an unjustified degree of accuracy. More than 300 specimens have been counted from each of the present samples from which the total population was estimated. On this basis it is possible to state that the percentage occurrences greater than 5% will have a probable error not exceeding 20%. Percentage occurrences smaller than 5% probably are not so reliable but are presented as such in the tables of dead populations to allow the reader to estimate the approximate number of specimens counted. Percentage occurrences smaller than 1% are represented in Table 4 by an "X" to indicate the occurrence of these species.

ECOLOGIC SIGNIFICANCE OF THE ESTERO FAUNAS

The marginal environment characteristic of the Estero de Punta Banda probably represents the most rigorous type of marine environment in which benthonic Foraminifera can flourish. Temperature and salinity measurements made in November, 1951, over a span of two days show large variations. Annual variations in the same area are more extreme according to Carl L. Hubbs (personal communication). In such an environment, marked variations in foraminiferal populations would be expected and have been reported from several marsh areas (Phleger and Walton, 1950; Parker, Phleger, & Peirson, 1953; Phleger, 1954).

There are three striking features of the Estero de Punta Banda fauna: (1) the discrete ranges of the species, (2) the occurrence of relatively few species, and (3) the predominantly arenaceous character of the fauna.

The discrete distributions of the marsh faunas appear to be related to the sharp variations in distribution of the marsh flora. Different foraminiferal assemblages seem to occur in areas characterized by marsh grasses and in general coincide with their distributions. Areas of marsh grasses support abundant populations of a great variety of invertebrates, and the air-water substrata boundary is generally covered by a thin layer of algae. The Foraminifera probably live in close contact with the continuously wetted surface of the grasses.

It is interesting that very few living specimens of the marsh species are found in the open ocean. If temperature and/or salinity alone controlled the distributions of these species they would be expected to occur in abundance in the open ocean where temperatures and salinities are within the range of those obtaining the marsh. Their distributions probably result from other ecologic factors, such as food association, etc., which limit these species to areas containing marsh grasses.

The occurrence of relatively few species in the marsh faunas may be due to the extreme variations of temperature and salinity in this environment. A variable environment generally would be expected to support a greater number of species than an environment characterized by small ranges in temperature and salinity, provided the variations are not extreme. Assuming abundant food and living space, the environmental variations of the marsh should include the optimum temperature and salinity for a large number of species. The extreme variations of temperature and salinity in the marsh apparently exceed the viable or reproduction limits of many species. There appear to be relatively few species whose tolerances fall within the limits of the ecologic variations found in the marsh environments.

The dominantly arenaceous character of the marsh fauna may be related to a deficiency in the calcium carbonate content of the marsh water. Two calcareous species were found living in the marsh area of the Estero de Punta Banda, *Elphidium* sp. and *Triloculina* sp. 2. "*Rotalia*" *beccarii* variants are abundant in the marshes of San Antonio Bay Texas (Parker, Phleger, & Peirson, 1953). The latter example may be due to storm overwash from the lagoon where abundant populations of "*Rotalia*" *beccarii* also are found.

Three species are found living in both the tidal channels and marshes. These species are able to withstand the extremes of the marshes but do not appear to be as re-

stricted in their environmental associations as do the marsh species. These are *Miliammina fusca*, *Proteonina* sp., and *Elphidium tumidum*. *Triloculina* sp. 2 and "*Rotalia*" *beccarii* are restricted to the tidal channels. The species in the tidal channels that are common in the bay indicate that certain open-ocean forms are able to survive in the channels. They further suggest that the channel environment is not so rigorous as the intertidal marsh environment, and that the conditions in the channel closely approximate those in the bay.

LIVING FORAMINIFERAL FAUNAS IN THE BAY

It is known that some Foraminifera have tolerances of temperature outside of which they cannot reproduce (Myers, 1936, p. 121). As with other groups of animals, it appears that these temperature tolerances are not the same for every species of Foraminifera. Phleger (1951b, 1952a, 1952b), Parker (1948, 1952a), and Natland (1933) have reported depth facies of Foraminifera which may be related to temperature changes, at least in part.

The areal distributions of the outer bay facies and the middle bay facies in Todos Santos Bay appear to be related to the bathymetry, and probably also to the associated temperature variations. It is interesting that all the species of the middle bay facies are arenaceous, imperforate forms. It is possible that some peculiarity of food requirements, feeding habits, or other ecological factors may influence these distributions.

The species of the marginal bay facies have wider distributions than the outer or middle bay facies, and generally are distributed over the area of coarser sediments (Text-fig. 6). The fact that this assemblage is most commonly associated with coarser sediments suggests that sediment type may exert some influence on the distributions of these species. This correlation may be fortuitous, however, and the distribution of this facies may be more closely related to the food requirements or to some other ecologic factor. This area of coarser sediments appears to have a pronounced effect on the benthonic organisms other than Foraminifera. Two species of brachiopods, several echinoids, and abundant encrusting organisms were collected in dredge samples from this area yet were not found elsewhere in the bay. Three species of Foraminifera, *Cibicides fletcheri*, *Cibicidina nitidula*, and *Planulina exorna*, were found living free and also attached to the larger sediment particles and shell fragments. It appears that sediment type may influence some distributions in this group either directly, or indirectly through food associations.

Geographic facies have been presented in addition to depth distributions for the primary purpose of delineating foraminiferal assemblages that may be related to ecological factors other than temperature. The geographic facies apparently indicate that areal distributions of species and groups of species may be influenced by sediment type, food associations, or other ecologic factors. These associations are not apparent from depth distributions which probably are more related to temperature variations.

DEPTH DISTRIBUTIONS OF LIVING FORAMINIFERA

In addition to faunal boundaries at 30 fathoms, 50 fathoms, 100 fathoms, and 350 fathoms, two general characteristics of the distributions of living Foraminifera stand out: (1) the relatively greater number of species in the shoaler depths, and (2) the wider distributions of the deep species. It can be seen from Text-figures 19–23 that the greatest number of species is restricted to or occur most abundantly at depths shoaler than 50 fathoms. Over 50% of the species are most abundant shoaler than 50 fathoms, and 67% are most abundant shoaler than 100 fathoms. This distribution suggests that the variable environment of the shoaler depths supports a greater variety of benthonic Foraminifera. The effect of the variable environmental conditions on the size of living populations is indicated by the productivity estimates presented on following pages. They suggest that depths between 20 and 50 fathoms are approximately 6 times as productive as the zone between 350 and 400 fathoms.

The variable environmental conditions characteristic of the shoaler depths apparently have a marked limiting effect on the distributions of the foraminiferal spe-

cies. Most of the species characterizing the 0–30 and 30–50 fathoms facies are distributed over relatively narrow depth ranges; they seldom occur over depth ranges greater than 100 fathoms (Text-figs. 19, 20, 21). The species characterizing facies deeper than 50 fathoms commonly range over hundreds of fathoms. This wider distribution of deeper-water species is apparently characteristic of distributions of benthonic organisms in the archi-benthic and abyssal-benthic environments (Ekman, 1953, p. 286). These wider distributions apparently reflect the more uniform environments characterizing the deeper water.

SEASONAL VARIATION OF LIVING POPULATION

As previously noted, individual species do not all have their maximum abundances during the same season. The seasonal peaks reflect relative abundances of different groups of species, one group occurring most abundantly in June and the other in August. Of the two peaks, however, August marks the season of greatest abundance of benthonic Foraminifera in this area. The temperature maximum in August suggests that warmer water may favor large populations of benthonic Foraminifera in the presence of abundant food.

It is believed that the population maxima in June and August reflect peaks of phytoplankton production in late spring and again in summer. Very little information is available on the food of Foraminifera. Glaessner (1947, p. 57) reports that they eat "diatoms and other algae, either alive or in a state of decay . . . copepod crustaceans . . . copepod larvae and infusoria as well as diatoms." Phleger (MS.) reports that they feed on any form of organic detritus. From these data, the foraminiferal populations would be expected to respond to the abundance of phytoplankton during the late spring and the summer months.

Myers (1942b) in his work on *Elphidium crispum* off Plymouth, England, reports that the growth and reproduction of Foraminifera are similar to those of the zooplankton, both of which respond to the abundance of food available in the microflora of the sea. He states further (op. cit., p. 334) that the season of maximum growth and reproduction of *Elphidium crispum* follows closely behind the spring flowering of the phytoplankton off Plymouth. The work of Myers has been a major source of information on the life cycle, food, habits, and reproduction of Foraminifera in the sea, but the variability of distribution and morphology between species probably precludes application of his specific data to all species.

The large variations in nearshore surface temperatures on the south side of Punta Banda, due to upwelling, apparently do not affect the composition of the foraminiferal fauna in this area. The populations of the samples collected in areas of upwelling are comparable to the populations from similar depths in the bay in both kind and number. Temperature measurements indicate that bottom temperatures at a depth of 50 fathoms in the area of upwelling are only a few degrees colder during times of upwelling than sediment temperatures at comparable depths in the bay. It is possible that the nearshore, shallow-water faunas would be affected by the relatively larger surface temperature variations.

The cold, upwelled water on the south side of Punta Banda during the late spring and summer months apparently is confined outside of Todos Santos Bay and has no noticeable effect on water temperatures in the bay. Temperature data in June suggest that the upwelled water extends northward toward the Todos Santos Islands but apparently is confined outside the bay by the outflowing bay water.

RATES OF PRODUCTION

The apparent rate of production of benthonic Foraminifera varies with depth and no generalization can be made concerning the rate of production for the entire area. Depth distributions of average living populations for all seasons (Text-fig. 16) show that there is an average of 104 living specimens per sample at depths shoaler than 50 fathoms. From 50 to 100 fathoms the living populations average 142 specimens per sample, and from 100 fathoms to the end of the seasonal traverse at approximately 600 fathoms, the average is 42 specimens. These data suggest that the zone of maximum production of benthonic Foraminifera in this area is at 50–100 fathoms.

Text-figure 16 is a scale agreement histo-

gram in which the depth shoaler than 50 fathoms is divided into 10-fathom intervals. This shows a prominent peak at 30–40 fathoms which is the actual depth of maximum production. This histogram includes all the stations from which living counts were made, and the large number of nearshore, low population stations from the February sampling lower the averages of the populations shoaler than 50 fathoms. The histogram of the seasonal traverses (Text-fig. 15) verifies the 30–40 fathom production maximum. Considering only those seasonal samples that were collected within the depth range of 20–50 fathoms, the average living population per sample is 193 specimens; the minimum value occurs during March with 25 specimens per sample, and the maximum population occurs during August, with 653 specimens per sample.

Myers (1942b, p. 336) found that populations of *Elphidium crispum* in Plymouth Sound varied from 245 individuals per square foot in February to 1,225 individuals per square foot in June. He concluded that since the life span of *E. crispum* in tidepools is one year, the annual rate of mortality is equal to the total number of individuals produced each year. He also concludes (op. cit., p. 338):

> "In the sublittoral zone the number of tests annually contributed to the sediments also approximates the maximum population observed including those which had survived from the preceding year."

If we assume that the life cycle of benthonic Foraminifera is one year, approximately 650 specimens per year per 10 cc. or 650,000 specimens per sq. m. are added to the sediment at 20–50 fathoms. The seasonal samples collected at 300–400 fathoms have an average population of 50 specimens per sample. The maximum number of specimens within this depth range occur in March with an average of 104 specimens per sample, and the minimum during November with an average of 25 specimens per sample. Assuming one year as the life cycle of benthonic Foraminifera, approximately 100 specimens per year per 10 cc. or 100,000 specimens per sq. m. are added to the sediment within this depth range. These data are very general and are given only as representing orders of magnitude. The assumption of one year for the life cycle of benthonic Foraminifera in the 20–50 fathom range may be valid, but in the deeper range (300–400 fathoms) the life cycle may be longer due to the much colder temperatures.

The average standing crop of living Foraminifera in Todos Santos Bay is approximately 193,000 specimens/sq. m. from 20 to 50 fathoms. Phleger (1951b, 1952b) made similar calculations on the continental shelf in the Gulf of Maine and the Gulf of Mexico. He found an approximate standing crop of 30,000 specimens/sq. m. in the Gulf of Maine and 10,000 specimens/sq. m. in the northwest Gulf of Mexico. These estimates were made from comparable samples and are from comparable depths. The reasons for these discrepancies in average standing crops of living Foraminifera are not apparent to the writer, but it is possible that Phleger's season of collection has some effect. The estimate of 193,000 specimens/sq. m. is a yearly average in contrast to the estimates from the Gulf of Maine and the Gulf of Mexico which are average populations at one season. It is suggested that the lower estimates may reflect seasons of lower production in the other areas. It also is suggested that Phleger's lower estimates may be due to the different methods used to recognize the living specimens; Millon's reagent in the Gulf of Maine, biuret reaction in the Gulf of Mexico, and rose bengal staining technique in the present study. Recent work in the Gulf of Mexico near the Mississippi Delta shows an average standing crop of 90,000 specimens/sq. m. using the rose bengal technique (Phleger, unpublished data). This estimate also was made at only one season but more closely approximates the yearly average of 193,000 specimens/sq. m. of this study.

NON-LIVING DISTRIBUTIONS

There are two striking differences in the distributions of living and dead specimens of the species found in this area: (1) differences in areal distribution, and (2) differences in size of populations. Differences in areal distributions of living and dead specimens of various species in this area are of considerable importance. Most ecological and faunal studies of benthonic Foraminifera have been made from dried samples and it has been assumed that dead populations in general

represent distributions of the living Foraminifera. Phleger (1951b, 1952b) has shown that this assumption is generally correct by considering the living populations as well as the dead. The results of the present study have shown that this assumption is valid only under certain conditions. The areas of largest populations of empty shells do not necessarily coincide with the areas of maximum abundances of living Foraminifera. This fact is due primarily to varying rates of sedimentation. In areas of little or no sedimentation, large populations of empty shells accumulate. Areas undergoing rapid sedimentation, on the other hand, might have a relatively small population of empty shells even though both areas have comparable living populations.

Areal plots of living and dead distributions in the present area suggest that dead populations generally occur over a somewhat wider areal and depth range than do the living populations. It is believed that dead population counts are valid in describing the composition and general distributions of living benthonic Foraminifera, unless contaminated with relict or fossil faunas, but cannot be considered as indicative of relative abundance.

SIGNIFICANCE OF POPULATION RATIOS

The L/D ratio is an index of the complex variables which control the living and dead populations at any location. The size of the living population results from the ability of the organisms to live and reproduce in the environment. It may be assumed that any given environment is supporting the maximum possible population of Foraminifera, and that the population will increase or decrease in response to changes in food supply, biologic competition, predators, or changes in the environment. The total living populations in the immediate area of Todos Santos Bay vary over a relatively small range. Even though the populations and distributions of individual species vary considerably, the small variation in the total living populations suggests that the bay environment can support relatively uniform numbers of living Foraminifera over most of its area. There is no indication that large variations in the productivity from place to place in the bay are responsible for the large variations in populations of empty tests.

The adaptability of the empty tests to preservation in the sediments is an important factor in the accumulation of large dead populations. In the depth ranges considered in this report there is no indication that appreciable destruction of empty tests occurs below the depth of vigorous abrasion (*i.e.*, the surf zone). Certain very fragile arenaceous forms rarely are found dead, such as *Reophax* sp. 1 and *R. gracilis*, but these constitute relatively small percentages of the total populations.

It appears that dilution by detrital sediment is the most important factor in determining the total dead population per unit volume of sediment. The L/D ratio appears to be a good index to relative rates of sedimentation in this area, since the total living populations vary little over the area of the bay. Where the L/D ratios are large, more detrital sediments are being deposited to dilute the dead populations than in areas where the L/D ratio is small. The areas of low L/D ratios in Todos Santos Bay correspond generally with the areas of sediment Group I. The sediment data indicate that little sediment is being deposited in the Group I area at the present time, and further that the sediments of Group I are not characteristic of the environment in which they are found but are "relict" sediments of a previous environment. The foraminiferal faunas of the area corresponding with Group I sediments also appear to be relict, at least in part. Several species were found in this area for which there were no living representatives. Occasional specimens of *Elphidium crispum* and the large populations of miliolids indicate an environment shoaler than the present depths. The portion of the dead populations in the relict area which represents a previous environment is not known since most species were representated by living forms. The relatively low rates of sedimentation in the relict area appear to be the primary factor causing the unusually large populations of dead Foraminifera. These large dead populations do not indicate high productivity, therefore, but do indicate low rates of sedimentation.

FOSSIL FAUNAS

Dead populations were counted from only one seasonal traverse. The dead populations of the samples in deeper water are relatively

large and contained several species which are not represented by living specimens. The species which are not found living are:

Angulogerina carinata Cushman
Astrononion stellatum Cushman & Edwards
Bulimina pagoda Cushman
B. subacuminata Cushman & Edwards
Cassidulina californica Cushman & Hughes
Eponides subtenera (Galloway & Wissler)
E. umbonatus (Reuss)
Gyroidina altiformis Stewart & Stewart
Planulina ariminensis d'Orbigny
Sigmoilina cf. *S. miocenica* Cushman
Uvigerina senticosa Cushman

These species are abundant in the surface sediment samples at most of the deeper stations.

At stations B-141, B-160, and B-144, the small coring tube penetrated the fine surface sediment and cored hard dark siltstone. These siltstones were found to contain abundant fossil Foraminifera. The age of these fossil assemblages was identified for the writer by Mr. Thomas Rothwell of the Richfield Oil Company.

Sample B-141 at a depth of 440 fathoms contains a fauna referred to the Venturian stage of the Pliocene (lower Pico). Sample B-160 at a depth of 265 fathoms contained a fauna identified as of middle Pico age (Wheelerian stage of Natland). Sample B-144 at a depth of 380 fathoms contained a fauna which was identified as characteristic of the upper Luisian stage of the Miocene. These fossil faunas all occurred only a few inches below the surface of the core. All of the species just listed, for which no living representatives were found, occur abundantly throughout the Pliocene and in the siltstones cored at stations B-141 and B-160. The presence of these non-living species in the Recent sediments and their abundances in the Tertiary rocks outcropping nearby suggest that they do not live on the continental shelf off Baja California, but are contaminants from the submarine reworking of the Tertiary rocks.

It is realized that the area sampled is small and the samples are few and that no generalization can be made concerning the effects of reworked Foraminifera in other areas. It also is realized that these species may occur living in deeper facies or may be so sparse that they were not found in the small area sampled by the cores. It appears certain, however, that these Tertiary rocks and their contained faunas outcropping at or near the surface of the continental shelf contaminate the Recent sediments.

SUMMARY OF CONCLUSIONS

1. The sediments of Todos Santos Bay can be divided into three groups on the basis of their median diameter, standard deviation, and skewness. Sediment Group II is composed of clean fine sand and covers most of the inner part of the bay. Sediment Group III is composed of micaceous silts and appears to be the seaward extension of Group II sediments. It is believed that these groups reflect the present environment of deposition. Sediment Group I is composed of coarse sand, encrusted cobbles and pebbles, abundant glauconite, and organic remains and does not appear to be in adjustment with the present environment. The sediment characteristics of this group, their geographic and bathymetric position, and the relationship with the other sediment groups suggest that they are relict and/or residual sediment of a previous environment.

2. The benthonic Foraminifera in Todos Santos Bay can be grouped into four areal assemblages. The outer bay and middle bay foraminiferal facies have limited distributions and are restricted to the deeper portion of the bay. These distributions apparently are related to depth changes and associated temperature variations. The marginal bay assemblage has a wider distribution and generally is found over the areas of coarser sediment. This assemblage does not appear to be restricted by depth or temperature variations, and it is suggested that these distributions may be related to variations in sediment type, abundance of food or other ecological factors. The species of the inner bay assemblage are most abundant in the shallow, nearshore area of the inner bay, but generally are distributed over the entire Todos Santos Bay. Their distributions do not appear to be as limited by depth changes or variations in sediment as do the species of other assemblages. These species probably have a greater tolerance for environmental changes than the previous groups.

3. Four depth facies have been established based on frequency distributions of individual species; less than 30 fathoms, 30–

50 fathoms, 50–100 fathoms, and deeper than 350–400 fathoms.

4. The areas of maximum populations of living Foraminifera do not coincide with the areas of maximum dead populations. The living specimens of a species generally are more restricted in their distributions than the dead specimens. Population counts of dead Foraminifera may be reliable only to define faunal compositions and general distributions of species.

5. Ratios of living and dead populations from sediment samples appear to be good indices of relative rates of sedimentation. Areas of low living-dead ratios suggest slow deposition and areas of high living-dead ratios suggest relatively faster deposition.

6. The production of benthonic Foraminifera varies seasonally in Todos Santos Bay and the maximum abundances occur in June and August. Each species apparently does not have its maximum abundance during the same season.

7. The population maxima in June and August apparently are related to the late spring and late summer flowering of phytoplankton in the area. The seasonal temperature maximum which occurs in August may influence the greater production during that month.

8. Many species of Foraminifera occurring in surface sediments have not been found living in the area. The occurrence of non-living, shallow-water species in the area of relict sediments suggest that part of the foraminiferal fauna may be relict and reflect a previous environment.

9. Two exposures of Middle Pliocene strata and one of Middle Miocene strata have been cored in place off Todos Santos Bay. The common occurrence of several non-living species in the surface sediments over or near these outcrops of older Tertiary sediments suggests that they may be contaminants and not representative of living populations. The occurrence of relict and/or fossil Foraminifera in modern sediments may be an important factor in interpreting distributions of modern Foraminifera.

THE BENTHONIC FORAMINIFERAL SPECIES AND THEIR DISTRIBUTION

The following is a brief discussion of the species of benthonic Foraminifera that were identified and used in this study. No attempt has been made to include detailed taxonomic discussion or complete synonomy of the species listed here. The synonomy includes only references to original descriptions of the species, and taxonomic discussion is limited to those species about which there is some question. A brief discussion of the distribution of living and dead specimens in the area of Todos Santos Bay is included for each species. The species are listed here in alphabetical order. The plates are arranged systematically.

AMMODISCUS PACIFICUS Cushman & Valentine
Plate 99, figure 11

Ammodiscus pacificus CUSHMAN & VALENTINE, Contrib. Dept. Geol. Stanford Univ., vol. 1, no. 1, p. 7, pl. 1, fig. 1.

The limited occurrence of this species of Foraminifera on the south side of Punta Banda in about 55 fathoms suggests that its distribution is controlled in the main by the colder water in this area. This area is characterized, during certain months, by upwelling.

AMMOTIUM PLANISSIMUM (Cushman)
Plate 99, figures 20–23

Haplophragmoides planissima CUSHMAN, 1927, Bull. Scripps Inst. Oceanog., Tech. ser., vol. 1, no. 10, p. 135, pl. 1, fig. 6.

This species is placed in the genus *Ammotium* (Loeblich & Tappan, 1953) because it tends to uncoil in the last chambers and the aperture becomes terminal. It differs from the genus *Ammobaculites* in that the last-formed chambers tend to uncoil but reach back to the coil at the inner margin. The specimens range from coarsely arenaceous forms, in the shallower end of their distribution (Pl. 99, figs. 20, 21) to almost entirely chitinous forms covered with a thin layer of fine silt or clay-size sediment particles at greater depths (Pl. 99, figs. 22, 23).

The depth range of the living specimens of this species is from 8 to 380 fms. Its distribution shows a marked peak between 50 and 100 fms. (Text-fig. 21). The geographic distribution in Todos Santos Bay is restricted to the area of finer sediments in and around the deeper portion.

ANGULOGERINA ANGULOSA (Williamson)

Uvigerina angulosa WILLIAMSON, 1858, Rec. Foram. Gt. Britain, p. 67, pl. 5, fig. 140.

This form is quite variable and generally smaller than the type specimens but appears to be the same species.

The depth range of this species is from 3 to 360 fathoms in Todos Santos Bay. It is most abundant between 20 and 100 fathoms. It has a wide geographic range with the greatest abundance in the area of relict sediments.

ANGULOGERINA CARINATA Cushman
Plate 102, figure 21

Angulogerina carinata CUSHMAN, 1927, Bull. Scripps Inst. Oceanog., Tech. ser., vol. 1, no. no. 10, p. 159, pl. 4, fig. 3.

This species was not found living in the area studied. The only recorded occurrences are at stations B-135, 136, 138, 141, and 141-1. All of these stations occur over or near outcrops of "fossil" sediments, and the specimens found are believed to be reworked from these older sediments.

ARENOPARRELLA MEXICANA (Kornfeld)
Plate 101, figures 1–3

Trochammina inflata (Montagu) var. *mexicana* KORNFELD, 1931, Contr. Stanford Dept. Geol., vol. 1, p. 86, pl. 13, figs. 5a–c.
Arenoparrella mexicana KORNFELD, 1951, Contr. Cushman Found. Foram. Res., vol. 2, pt. 3, p. 96, pl. 11, figs. 4 a–c.

There is no other known occurrence of this species on the west coast of North America, but it is common in the shallow nearshore areas and marshes of the Gulf Coast of Louisiana, Mississippi, Alabama, and Texas.

Living representatives of this species only occur in the marsh areas of the Estero de Punta Banda and are slightly smaller than the Gulf Coast individuals. Dead specimens are common in the marsh areas and the channel stations.

ASTRONONION STELLATUM
Cushman & Edwards
Plate 101, figure 21

Astrononion stellatum CUSHMAN & EDWARDS, 1937, Contr. Cushman Lab. Form. Res., vol. 13, p. 32, pl. 3, figs. 9–11.

No living representatives of this species were found in the samples studied. Only one specimen was found in the bay. The other occurrences were at stations B-137, 138, 139, and 140. The specimens recorded from these stations are apparently mixed with reworked material and may represent an ancient environment.

BIFARINA HANCOCKI Cushman & McCulloch
Plate 101, figure 22

Bifarina hancocki CUSHMAN & MCCULLOCH, 1942 Allan Hancock Pacific Exped., vol. 6, no. 4, p. 225, pl. 28, figs. 13–19.

This species has a spotty distribution in Todos Santos Bay in depths of 6 to 27 fathoms. It occurs in the greatest abundance at station B-66 in 27 fathoms.

BOLIVINA ACUMINATA Natland
Plate 102, figure 5

Bolivina acuminata NATLAND, 1946, in CUSHMAN & GRAY, Cushman Lab. Foram. Res., Spec. Publ. 19, p. 34, pl. 24, fig. 46.
Bolivina subadvena Cushman var. *serrata* NATLAND, 1938, Bull. Scripps Inst. Oceanog. Tech. ser., vol. 4, p. 145, pl. 5, figs. 8, 9.

The living-distribution curve of this species shows a maximum abundance between 50 and 100 fathoms (Text-fig. 21) in Todos Santos Bay. The total depth range is from 3 250 fathoms. It has a restricted geographic distribution and occurs most commonly in the deeper portions of the bay. It is one of the more common species in the depth range just mentioned.

BOLIVINA ARGENTEA Cushman
Plate 101, figures 26, 27

Bolivina argentea CUSHMAN, 1926, Contr. Cushman Lab. Foram. Res., vol. 2, pt. 2, p. 42, pl. 6, fig. 5.

The only occurrences of this species in Todos Santos Bay are confined to the deeper portions. The living specimens show a fairly restricted depth range, from 150 to 350 fathoms. Its frequency distribution has a marked peak at 250–300 fathoms (Text-fig. 22).

BOLIVINA MINUTA Natland
Plate 102, figure 2

Bolivina minuta NATLAND, 1938, Bull. Scripps Inst. Oceanog., Tech. ser., vol. 4, no. 5, p. 146, pl. 5, fig. 10.

This species shows a constant living distribution below 200 fathoms. No marked

peak occurs in its frequency distribution (Text-fig. 23), but it appears to be a good indicator of water depths greater than 200 fathoms off Mexico.

Bolivina pacifica Cushman & McCulloch
Plate 102, figure 4

Bolivina acerosa Cushman var. *pacifica* Cushman & McCulloch, 1942, Allan Hancock Pacific Exp., vol. 6, no. 4, p. 185, pl. 21, figs. 2, 3.

The living depth range of this species in Todos Santos Bay is from 18 to 490 fathoms, and its frequency curve shows an excellent distribution with the peak at 50 to 100 fathoms. It is restricted to the deeper portions of the bay between Punta Banda and the Todos Santos Islands.

Bolivina cf. B. pseudoplicata Heron-Allen & Earland
Plate 102, figure 1

Bolivina pseudoplicata Heron-Allen & Earland 1930, Jour. Roy. Micr. Soc., ser. 3, vol. 50, p. 81, pl. 3, figs. 36–40.

This form, which is the same assigned to *B. pseudoplicata* by Cushman and McCulloch (1942), has a widespread occurrence along the eastern Pacific coast.

No living representatives of the species were found in this study. The distribution in Todos Santos Bay is "spotty," and only a few specimens were found.

Bolivina seminuda Cushman

Bolivina seminuda Cushman, 1911, U. S. Nat. Mus., Bull. 71, pt. 2, p. 34, text fig. 55.

No living specimens of the species were found in this study. It occurs at only two stations in Todos Santos Bay but is present in sample B-141-1 which contains a pure Pliocene assemblage. It is believed that this species, where it occurs in Recent sediments, represents reworking of a fossil fauna.

Bolivina spissa Cushman
Plate 101, figures 24, 25

Bolivina subadvena Cushman var. *spissa* Cushman, 1926, Contr. Cushman Lab. Foram. Res., vol. 2, pt. 2, p. 45, pl. 6, figs. 8a–b.

This species is characteristic of water depths greater than 189 fathoms off Todos Santos Bay. The frequency distribution of the living specimens (Text-fig. 23) shows a marked maximum between 350 and 400 fathoms, and it generally occurs in relatively high frequencies within this range.

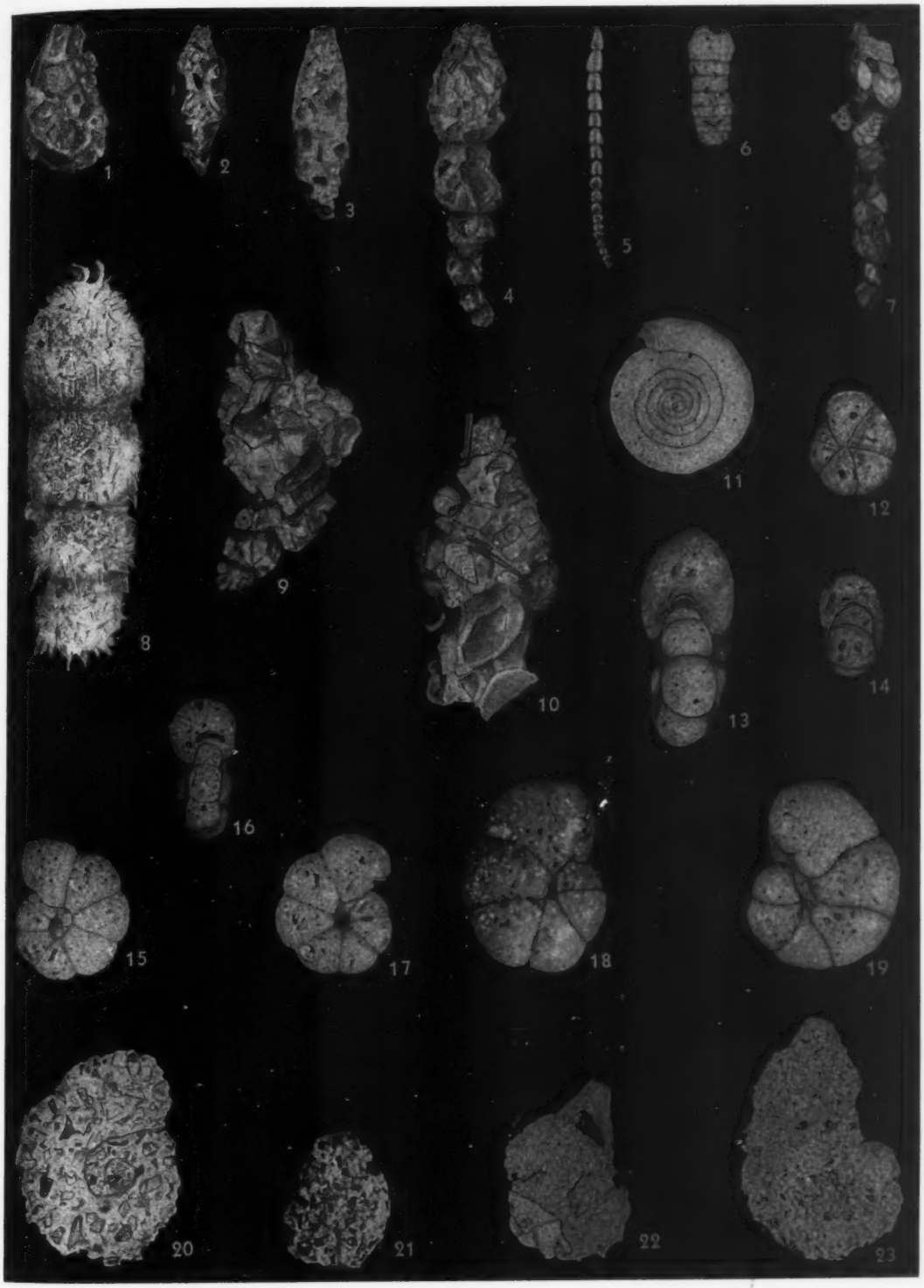
Bolivina striatella Cushman
Plate 102, figure 3

Bolivina advena Cushman var. *striatella* Cushman, 1925, Contr. Cushman Lab. Foram. Res., vol. 1, pt. 2, p. 30, pl. 5, figs. 3a–b.

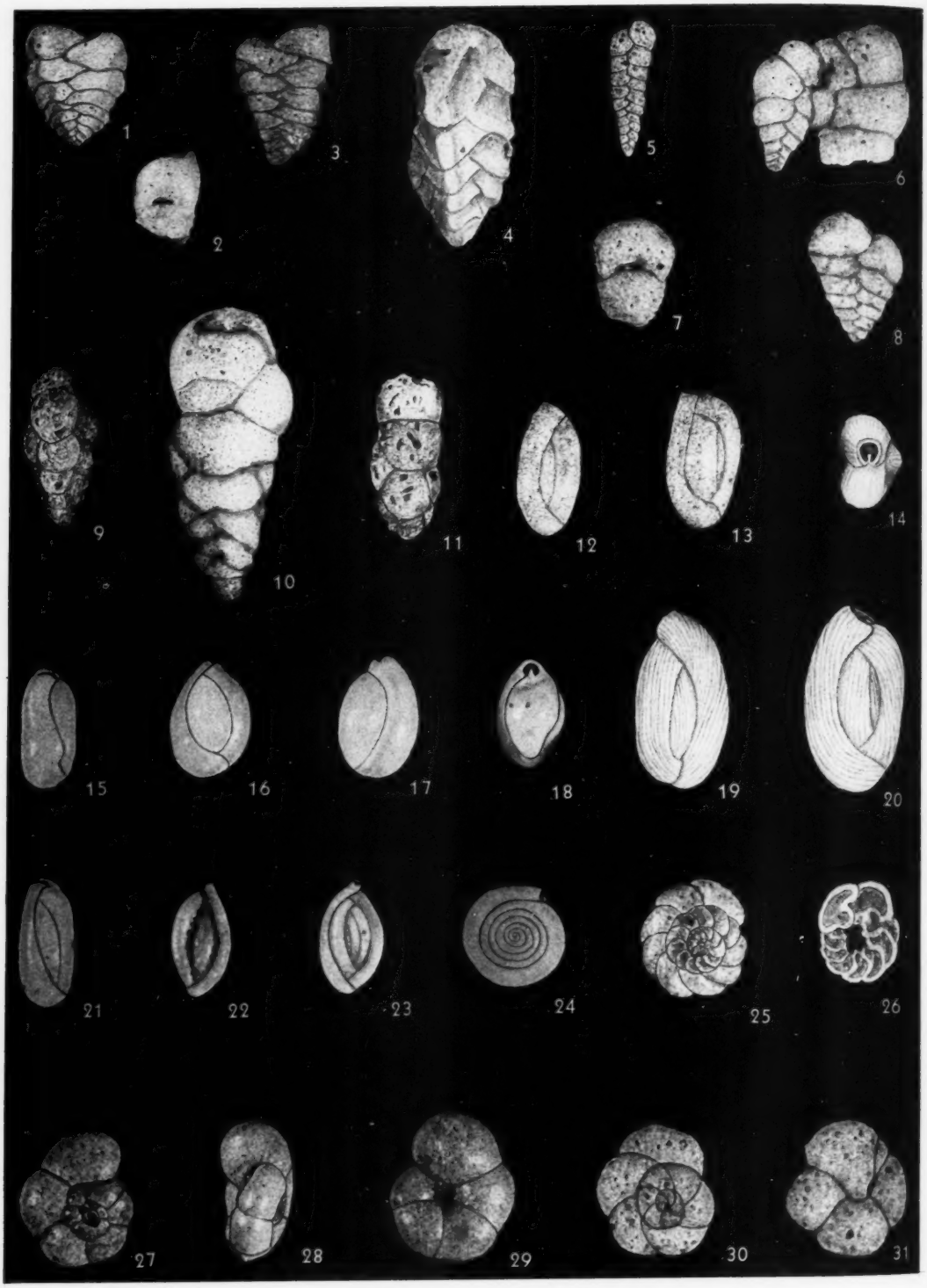
This species was described from the Monterey shale (Miocene) of California and has also been reported from the Pliocene of California. It has been reported in Recent sediments from off California in 14 to 123 fms. Bandy (1953) has included this species under a new variety, *B. advena* Cushman var. *actula* Bandy on the basis of the arcuate rather than sinuate sutures. The specimens from Todos Santos Bay are variable, and even though some have arcuate sutures in the early chambers, the sutures of the later-formed chambers are sinuate and the writer feels that a new variety is not warranted.

Explanation of Plate 99

Fig. *1*—*Proteonina atlantica* Cushman. ×46.
2, 3—*Proteonina* sp. (2) ×46; (3) ×70.
4—*Reophax scorpiurus* Montfort. ×30.
5—*Reophax gracilis* (Kiaer). ×30.
6—*Reophax* sp. 2. ×70.
7—*Reophax* sp. 1. ×46.
8—*Reophax horrida* Cushman. ×21.
9—*Reophax curtus* Cushman. ×30.
10—*Reophax agglutinatus* Cushman. ×33.
11—*Ammodiscus pacificus* Cushman & Valentine. ×26.
12, 14—*Recurvoides* spp. ×94.
13, 18, 19—*Labrospira* cf. *L. columbiensis* (Cushman). ×46.
15–17—*Labrospira* cf. *L. advena* (Cushman). ×46.
20–23—*Ammolium planissimum* (Cushman). ×21.



Walton, Living Foraminifera from Baja California



Walton, Living Foraminifera from Baja California

Bandy records the species from 200 to 800 ft. off San Diego.

Living specimens of this species are apparently restricted to depths shallower than 96 fathoms in Todos Santos Bay. Its frequency distribution shows a peaked tendency between 20 and 30 fathoms.

BOLIVINA VAUGHANI Natland
Plate 101, figure 23

Bolivina vaughani NATLAND, 1938, Bull. Scripps Inst. Oceanog., Tech. ser., vol. 4, p. 146, pl. 5, fig. 11.

Distribution of living specimens of this species shows the maximum frequency at less than 10 fathoms in Todos Santos Bay. The depth range, however, is from 6 to 215 fathoms. Only one specimen is recorded from a depth of 215 fathoms which is at the base of a steep slope and may represent a displacement from shallower water. The species has a wide areal distribution in the immediate area of the bay.

BUCCELLA FRIGIDA (Cushman)
Plate 103, figures 3, 4

Pulvinulina frigida CUSHMAN, 1922, Contr. Can. Biol., p. 12.
Eponides frigida (Cushman), CUSHMAN, 1941, Contr. Cushman Lab. Foram. Res. vol. 17, p. 37, pl. 9, figs. 16, 17.
Bucella frigida (Cushman), ANDERSEN, 1952, Jour. Wash. Acad. Sci., vol. 42, no. 5, p. 144, figs. 4a–6c.

The living depth range of this species is from 6 to 122 fathoms in Todos Santos Bay. Its frequency distribution is fairly constant but it tends to peak around 100 fathoms. Both living and dead specimens have a wide distribution in this area.

BULIMINA AFFINIS d'Orbigny
Plate 102, figure 15

Bulimina affinis D'ORBIGNY, 1840, in DE LA SAGRA, Hist. Phys. Pol. Nat. Cuba, "Foraminiferes," vol. 6, p. 109, pl. 2, figs. 25, 26. See *Globobulimina* spp.

BULIMINA DENUDATA Cushman & Parker
Plate 102, figure 8

Bulimina denudata CUSHMAN & PARKER, 1938, p. 57, pl. 10, figs. 1, 2.

The living specimens of *B. denudata* have a depth range of 19 to 215 fms. in Todos Santos Bay. The frequency distribution shows a definite maximum between 50 and 100 fms. and is skewed toward deeper water.

BULIMINA EXILIS TENUATA (Cushman)
Plate 102, figure 6

Buliminella subfusiformis Cushman var. *tenuata* CUSHMAN, 1927, Bull. Scripps Inst. Oceanog., Tech. ser., vol. 1, p. 149, pl. 2, fig. 9.
Bulimina exilis H. B. Brady var. *tenuata* (Cushman), CUSHMAN & PARKER 1947, U. S. Geol. Surv. Prof. Paper 210 D, p. 124, pl. 28, fig. 29.
Buliminella exilis (H. B. Brady), in BANDY, 1953, Jour. Paleontology, Vol. 27, p. 176, pl. 25, figs. 9a–b.

No living specimens of this species were found in the area studied. It occurred only on the outer end of the long traverse at stations B-138, 140, 141, and 141-1. These spec-

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EXPLANATION OF PLATE 100

FIGS. *1, 2, 3*—*Gaudryina* cf. *G. subglabrata* Cushman & McCulloch. ×46.
4—*Gaudryina arenaria* Galloway & Wissler. ×46.
5—*Textularia* cf. *T. earlandi* Parker. ×46.
6—*Rudigaudryina inepta* Cushman & McCulloch. ×33.
7, 8—*Textularia* cf. *T. schencki* Cushman & Valentine. ×46.
9—*Eggerella advena* (Cushman). ×70.
10, 11—*Goësella flintii* Cushman. ×21.
12, 13—*Miliammina fusca* (H. B. Brady). ×46.
14, 19, 20—*Quinqueloculina* sp. (14, 20) ×46; (19) ×33.
15, 21—*Triloculina* sp. 2 ×46.
16–18—*Triloculina* sp. 1×70.
22, 23—*Sigmoilina* cf. *S. miocenica* Cushman. ×46.
24—*Cornuspira* sp. ×70.
25, 26—*Trochammina kellettae* Thalmann. ×46.
27–29—*Trochammina inflata* (Montagu). ×46.
30, 31—*Trochammina pacifica* Cushman. ×46.

imens are believed to be reworked from ancient sediments outcropping on the continental shelf.

BULIMINA PAGODA Cushman
Plate 102, figure 9

Bulimina pagoda Cushman var. *hebespinata* R. E. & K. C. Stewart, CUSHMAN & MCCULLOCH, 1948, Allan Hancock Pacific Exped., vol. 6, no. 5, p. 244, pl. 30, fig. 6; NATLAND, 1933, Bull. Scripps Inst. Oceanog., Tech. ser., vol. 3, no. 10.

Bulimina pagoda CUSHMAN, 1927, Bull. Scripps Inst. Oceanog., Tech. ser., vol. 1, p. 152, pl. 2, fig. 16.

No living specimens of this species were found in the area studied. It occurs only in samples B-141 and 141-1. B-141-1 at a depth of 1 inch in a core contains a pure Pliocene fauna in a dark siltstone. The occurrence of this species in the Recent sediments at station B-141 is attributed to reworking of the underlying Pliocene siltstones.

BULIMINA SPINIFERA Cushman
Plate 102, figure 7

Bulimina spinifera CUSHMAN, 1927, Bull. Scripps Inst. Oceanog., Tech. ser., vol. 1, p. 151, pl. 2, fig. 15.

For the distribution of this species see *Globobulimina* spp.

BULIMINA SUBACUMINATA Cushman & R. E. Stewart
Plate 102, figure 10

Bulimina subacuminata CUSHMAN & R. E. STEWART, 1931, Trans. San Diego Soc. Nat. Hist., vol. 6, no. 2, p. 65, pl. 5, figs. 2, 3a–b.

No living specimens of this species were found in the area studied. Dead specimens were recorded only from stations B-139, 140, 141, and 141-1. The samples were taken in an area of outcropping Pliocene strata and are considered to be reworked specimens.

BULIMINA SUBAFFINIS Cushman
Plate 102, figure 14

Bulimina subaffinis CUSHMAN, 1921, U. S. Nat. Mus., Bull., 100, vol. 4, p. 166, text figs. 7a, b.

See *Globobulimina* spp.

BULIMINELLA ELEGANTISSIMA (d'Orbigny)
Plate 102, figure 17

Bulimina elegantissima D'ORBIGNY, 1839, Voy. Amer. Merid., vol. 5, pt. 5, "Foraminiferes," p. 51, pl. 7, figs. 13, 14.

Scattered occurrences of living specimens of this species range from 5 to 165 fathoms in Todos Santos Bay. It occurs most abundantly, however, between 10 and 20 fathoms, and the deeper occurrences appear to be displacements from shoaler water.

CANCRIS AURICULA
(Fichtel & Moll)
Plate 102, figures 25, 26

Nautilus auricula FICHTEL & MOLL, 1803, Test. Micr., var. a, pl 108, pl. 20, figs. 2a–c; var. b, p. 110, pl. 20, figs. 2d–f.

Living specimens of this species occur at depths of from 30 to 300 fathoms in Todos Santos Bay. It is most abundant between 150 and 200 fathoms and appears to be most characteristic of the depth range 50 to 200 fathoms.

CASSIDULINA CALIFORNICA
Cushman & Hughes
Plate 103, figure 25

Cassidulina californica CUSHMAN & HUGHES, 1925, Contr. Cushman Lab. Form. Res., vol. 1, no. 1, p. 12, pl. 2, figs. 1 a–c.

This species was not found living in the area studied. It occurs dead over the area of relict sediments in Todos Santos Bay but is most abundant over or near the outcrops of Pliocene sediments on the continental shelf. It is believed that this species does not represent a part of the living fauna in this area.

CASSIDULINA DELICATA Cushman
Plate 103, figures 28, 29

Cassidulina delicata CUSHMAN, 1927, Bull. Scripps Inst. Oceanog., vol. 1, p. 168, pl. 6, fig. 5.

This species does not occur living shoaler than 250 fathoms in the Todos Santos Bay area. It occurs in all samples deeper than 250 fathoms and shows a slight maximum between 350 and 400 fathoms. Dead specimens of this species are more abundant and occur over a greater depth range than living specimens.

CASSIDULINA LAEVIGATA d'Orbigny
Plate 104, figures 2, 7

Cassidulina laevigata D'ORBIGNY, 1826, Ann. Sci. Nat., vol. 1, p. 282 pl. 15, figs. 4, 5; Modeles, no. 41.

This species does not occur living shallower than 250 fathoms in the area of Todos Santos Bay. It occurs most abundantly between 350 and 400 fathoms but appears to

be characteristic of depths greater than 350 fathoms. The dead specimens of this species approximately correspond with the living specimens.

CASSIDULINA LIMBATA
Cushman & Hughes
Plate 103, figure 30

Cassidulina limbata CUSHMAN & HUGHES, 1925, Contr. Cushman Lab. Foram. Res., vol. 1, pt. 1, p. 12, pl. 2, figs. 2a–c.

Living specimens of this species do not occur deeper than 100 fathoms in Todos Santos Bay. They are most abundant between 20 and 30 fathoms, with the greatest abundance at station B-83 in 26 fathoms. Dead specimens occur as deep as 490 fathoms in the vicinity of outcropping Pliocene strata but do not appear to reflect a living population at this depth.

CASSIDULINA SUBGLOBOSA
H. B. Brady variants
Plate 103, figure 21

Cassidulina subglobosa H. B. BRADY, 1881, Quart. Jour. Micr. Sci., n. ser., vol. 21, pt. III, p. 60; ———, 1884, Rep't. Voy. *Challenger*, Zool., vol. 9, pl. 54, figs. 17a–c.

Living specimens of this species occur from 5 to 150 fathoms but are most abundant between 20 and 30 fathoms. Dead specimens and the variety *G. subglobosa quadrata* constitute large percentages of dead populations in the areas of relict sediments in Todos Santos Bay and occur as deep as 490 fathoms. These widespread occurrences of dead specimens appear to reflect, at least in part, relict and/or fossil faunas and do not represent living populations.

CASSIDULINA TORTUOSA
Cushman & Hughes
Plate 103, figures 26, 27

Cassidulina tortuosa CUSHMAN & HUGHES, 1925, Contr. Cushman Lab. Foram. Res., vol. 1, pt. 1, p. 14, pl. 2, figs. 4a–c.

This species only occurs living at depths shoaler than 50 fathoms in Todos Santos Bay, and is most abundant between 40 and 50 fathoms. Dead specimens are very abundant in the areas of relict sediments but apparently do not reflect similar abundances in living populations. The species occurs dead down to 215 fathoms in areas of considerable relief, and such occurrences apparently indicate displacement from shallow water.

CASSIDULINA sp.
Plate 104, figures 3, 4

This species is similar to *C. islandica* Norvang var. *minuta* Norvang, but differs in that the test is more compressed.

This form occurs living in the area of Todos Santos Bay from 20 to 300 fathoms with its maximum abundance between 40 and 50 fathoms. Dead specimens occur as deep as 490 fathoms but do not appear to reflect living populations at this depth.

CASSIDULINOIDES sp.
Plate 104, figure 1

This species is similar to *C. simplex* Cushman & Todd from the Miocene of Jamaica but is broader, more compressed, and generally larger.

It is recorded from only one station at 155 fathoms in Todos Santos Bay.

CHILOSTOMELLA OVOIDEA Reuss
Plate 104, figures 6, 15

Chilostomella ovoidea REUSS, 1850, Deukschr. Akad. Wiss., vol. 1, p. 380, pl. 48, fig. 12.

The population counts of *C. ovoidea* include a smaller species which is similar to *C. mediterranensis* Cushman & Todd (Pl. 104, fig. 15).

Living specimens of this species have a wide range of occurrence between 50 and 600 fathoms. Its frequency distribution shows a definite maximum between 350 and 400 fathoms. Dead specimens also occur over a wide depth range but are generally most abundant deeper than 250 fathoms

CIBICIDES FLETCHERI
Galloway & Wissler
Plate 104, figures 11, 12

Cibicides fletcheri GALLOWAY & WISSLER, 1927, Journ. Paleontology, vol. 1, p. 64, pl. 10, figs. 8, 9.

The living specimens of this species are very common in Todos Santos Bay and constitute large percentages of the living populations in the marginal bay facies. Isolated specimens are found as deep as 215 fathoms, but the species occurs most abundantly between 10 and 30 fathoms. This species likewise constitutes large percentages of the dead populations in the marginal bay facies but occurs as deep as 380 fathoms.

It is common in the late Tertiary sediments of California, and the wide distribution of dead specimens may indicate reworking of "fossil" strata.

CIBICIDES GALLOWAYI
Cushman & Valentine
Plate 104, figures 16, 21

Cibicides gallowayi CUSHMAN & VALENTINE, 1930, Contr. Dept. Geol. Stanford Univ., vol. 1, no. 1, p. 30, pl. 10, figs. 4a–c.

Living specimens of this species occur rarely between 5 and 35 fathoms in Todos Santos Bay. Dead specimens occur as deep as 215 fathoms but apparently indicate displacement from shoaler water.

CIBICIDES MCKANNAI
Galloway & Wissler
Plate 104, figures 13, 14

Cibicides mckannai GALLOWAY & WISSLER, 1927, Journ. Paleontology, vol. 1, p. 65, pl. 10, figs. 5, 6.

Living specimens of this species range from 20 to 100 fathoms but occur most abundantly between 30 and 50 fathoms. Dead specimens occur as deep as 490 fathoms, but these deeper occurrences may reflect reworking of fossil faunas as this species is common in both the Pliocene and Pleistocene of California.

CIBICIDES SPIRALIS Natland
Plate 104, figures 8, 9

Cibicides spiralis NATLAND, 1938, Bull. Scripps Inst. Oceanog., Tech. ser., vol. 4, no. 5, p. 151, pl. 7, figs. 7a–c.

This species was not found living in the area studied. It occurs dead in several deep stations near outcrops of Pliocene strata and may reflect reworking of these older sediments.

CIBICIDINA NITIDULA Bandy
Plate 104, figures 17–19

Cibicidina basiloba (Cushman) var. *nitidula* BANDY, 1953, Jour. Paleontology, vol. 27, p. 178, pl. 22, figs. 3a–c.

This species occurs living between 10 and 50 fathoms in relatively low frequencies. It is distributed generally over the area of coarse sediments in Todos Santos Bay and is commonly attached to the larger sediment particles and shell fragments. Dead specimens occur as deep as 215 fathoms at the base of the steep scarp between the Todos Santos Islands and Punta Banda and apparently have been displaced from shoaler water.

CORNUSPIRA sp.
Plate 100, figure 24

This species was encountered rarely in this study, and not enough specimens were were found to warrant an identification.

Living specimens occur rarely from 7 to 110 fathoms in Todos Santos Bay. Dead specimens occur more abundantly over approximately the same depth range.

DISCORBIS spp.
Plate 102, figures 27–29

The species of *Discorbis* encountered in this study were extremely variable and graded into one another. As they all occurred together, they were not differentiated. The most common and most typical of these forms are figured on Plate 102.

Living specimens occur from 5 to 40 fathoms in Todos Santos Bay, with one isolated occurrence at 110 fathoms. Dead specimens are very abundant and constitute large percentages of the dead populations.

DYOCIBICIDES BISERIALIS
Cushman & Valentine
Plate 104, figures 22, 23

Dyocibicides biserialis CUSHMAN & VALENTINE, 1930, Contr. Dept. Geol. Stanford Univ., vol. 1, no. 1, p. 31, pl. 10, figs. 1, 2a–b.

This species was described from off the coast of California and has been reported from 10 to 12 fms. It is also reported from the coast of Washington by Cushman & Todd (1947). *D. perforata* Cushman & Valentine was encountered rarely in this study and is included in the population counts of *D. biserialis*.

Living specimens of this species do not occur deeper than 30 fathoms in Todos Santos Bay and are most commonly attached to large sediment particles and shell fragments. Dead specimens occur as deep as 215 fathoms and apparently indicate displacement from shallow water.

DISCORINOPSIS cf. D. AGUAYOI
(Bermudez)
Plate 103, figures 6, 7

Discorbis aguayoi BERMUDEZ, 1935, Mem. Soc. Cubana, Hist. Nat., vol. 9, no. 3, p. 204, pl. 15, figs. 10–14.

Discorinopsis vadescens CUSHMAN & BRONNIMANN, 1948, Contr. Cushman Lab. Foram. Res., vol. 24, pt. 1, p. 20, pl. 4, figs. 9, 10.

This species was encountered in only three stations in the marsh subfacies in the Estero de Punta Banda. It was not found living in the area studied.

EGGERELLA ADVENA (Cushman)
Plate 100, figure 9

Verneuilina advena CUSHMAN, 1922, Contr. Canadian Biol., no. 9, p. 141.
Verneuilina polystropha CUSHMAN [not Reuss], 1920, Rept. Canadian Arctic Exped., vol. 9, p. 8, pl. 1, fig. 5.

According to Parker (1952, p. 404), "This species was first referred to *Verneuilina polystropha* Cushman, 1920 . . . [and] the Arctic specimens should form the basis for the conception of the species." The specimens from Todos Santos Bay were compared with Gulf of Mexico and Cape Cod Bay specimens and some from the Canadian Arctic. They are smaller, more sharply tapered, and generally more coarsely arenaceous. Some appear to be multiserial in the initial chambers and are thus referred to this species.

Living specimens of this species occur from 5 to 100 fathoms in Todos Santos Bay with their maximum abundance shallower than 10 fathoms. Dead specimens occur as deep as 215 fathoms along with other displaced shallow-water species and are generally abundant in most of the bay samples.

EHRENBERGINA COMPRESSA Cushman
Plate 104, figures 5, 10

Ehrenbergina compressa CUSHMAN, 1927, Bull. Scripps Inst. Oceanog., Tech. ser., vol. 1, no. 10, p. 168, pl. 6, fig. 7.

This species does not occur living in the area of Todos Santos Bay. Dead specimens were found at three stations (266, 375, and 480 fathoms) over or near outcrops of Pliocene strata and are thought to represent reworking of the Pliocene sediments.

ELPHIDIUM CRISPUM (Linné)
Plate 101, figure 11

Nautilus crispus LINNÉ, 1758, Syst. Nat., ed. 10, p. 709; ed. 13 (Gmelins), 1788, p. 3370 (Plancus de Conch), p. 10, pl. 1, fig. 2.

This species has not been found living in the area of Todos Santos Bay. Dead specimens occur in the area of relict sediments and are believed to be part of the associated relict fauna which represents a previous environment of deposition.

ELPHIDIUM SPINATUM
Cushman & Valentine
Plate 101, figure 12

Elphidium spinatum CUSHMAN & VALENTINE, 1930, Contrib. Dept. Geol. Stanford Univ., vol. 1, no. 1, p. 31, pl. 6, figs. 1a–2.

This species was found living at depths shallower than 20 fathoms in Todos Santos Bay. Dead specimens were recorded from several stations but in low frequencies. Dead specimens also were encountered at a few stations in the channels of the Estero de Punta Banda.

ELPHIDIUM TRANSLUCENS Natland
Plate 101, figure 7

Elphidium translucens NATLAND, 1938, Bull. Scripps Inst. Oceanog., Tech. ser., vol. 4, no. 5, p. 144, pl. 5, figs. 3, 4.

Living specimens of this species do not occur deeper than 30 fathoms in Todos Santos Bay. They occur most abundantly between 0 and 10 fathoms. Dead specimens occur at several stations in the bay to depths of 215 fathoms. The isolated occurrences at 215 fathoms appear to be displaced from shallow water. Dead specimens also occur in a few stations in the Estero de Punta Banda.

ELPHIDIUM TUMIDUM Natland
Plate 101, figures 8, 9

Elphidium tumidum NATLAND, 1938, Bull. Scripps Inst. Oceanog., Tech. ser., vol. 4, no. 5, p. 144, pl. 5, figs. 5, 6.

Living specimens of this species were recorded only from stations shallower than 30 fathoms in Todos Santos Bay. They occur most abundantly between 10 and 20 fathoms. Living specimens were also recorded from both the marsh and channel subfacies in the Estero de Punta Banda. Dead specimens are common over approximately the same depth range as the living individuals. Dead specimens were very abundant in the channel stations of the Estero de Punta Banda.

ELPHIDIUM sp.
Plate 101, figures 10, 15

This species is similar to *E. galvestonensis* Kornfeld but differs from that species in that the umbilical plug is smaller and the test generally is more compressed.

Living specimens of this species have been found only in the marsh subfacies of the Estero de Punta Banda. Dead specimens occur commonly in the channel stations of the estero.

EPISTOMINELLA SMITHI
(R. E. & K. C. Stewart)
Plate 103, figures 22, 23

Pulvinulinella smithi R. E. & K. C. STEWART, 1930, Journ. Paleontology, vol. 4, p. 70, pl. 9, fig. 4.

This species occurs living between 200 and 400 fathoms in the area of Todos Santos Bay in relatively low numbers. Only five living specimens were found. Dead specimens occur most abundantly in the offshore traverse at 200 to 400 fathoms.

EPONIDES cf. E. REPANDUS
(Fichtel & Moll)
Plate 103, figures 8, 9

Nautilus repandus FICHTEL & MOLL, 1798, Test. Micro., p. 35, pl. 3, figs. a–d.

Some of the specimens included in the population counts of *E.* cf. *E. repandus* probably belong in the genus *Poroeponides*. These specimens were not differentiated due to the paucity of specimens encountered in this study.

This species did not occur living in the present area. Dead specimens were common in the immediate vicinity of relict sediments and are believed to represent a previous environment.

EPONIDES SUBTENERA
(Galloway & Wissler)
Plate 103, figures 1, 2

Rotalia subtenera GALLOWAY & WISSLER, 1927, Jour. Paleontology, vol. 1, no. 1, p. 60, pl. 10, fig. 4.

This species was not found living in the Todos Santos Bay area. Dead specimens occur in samples of the offshore traverse in the area of outcropping Pliocene sediments and are thought to be reworked from the Pliocene fauna.

EPONIDES UMBONATUS (Reuss)

Rotalina umbonata REUSS, 1851, Zeitsch. deutsch. geol. Ges., Bd. 3, p. 75, pl. 5, figs. 35a–c.

This species was not found living in the area of Todos Santos Bay. It occurred dead only at station B-141 over outcropping Pliocene sediments and is thought to be a reworked species.

GAUDRYINA ARENARIA
Galloway & Wissler
Plate 100, figure 4

Gaudryina arenaria GALLOWAY & WISSLER, 1927, Jour. Paleontology, vol. 1, p. 68, pl. 11, fig. 5.

This species occurs living in low frequencies between 20 and 150 fathoms in Todos Santos Bay. Its frequency distribution shows no marked maximum within this depth range. Dead specimens are recorded as deep as 215 fathoms.

GAUDRYINA cf. G. SUBGLABRATA
Cushman & McCulloch
Plate 100, figures 1–3

Gaudryina subglabrata CUSHMAN & MCCULLOCH, 1939, Allan Hancock Pacific Exped., vol. 6, no. 1, p. 92, pl. 8, figs. 5–7.

Living specimens of this species occur between 10 and 40 fathoms in Todos Santos Bay. The maximum abundance is between 10 and 20 fathoms, and dead specimens occur as deep as 375 fathoms in the samples of the offshore traverse.

GLOBOBULIMINA spp.
Plate 102, figures 13–16

Globobulimina sp. b HÖGLUND, 1947, Zool. Bidrag Fran Uppsala, Bd. 26, p. 245, pl. 21, figs. 2, 7; pl. 22, fig. 3; text figs. 238, 242.

The reasons for grouping several species in this population count are given in the discussion of the genus *Globobulimina* by Höglund (1947). This group includes species that have been identified from off the west coast of North America as *G. pacifica* Cushman, *Bulimina* (*Desinobulimina*) *auriculata* Bailey, *B. affinis* d'Orbigny, *B. subaffinis* Cushman, and what has been called *B. ovata* and *B. ovula* by Natland (1933) and Crouch (1952). *B. spinifera* Cushman has been included in this count as it only occurs rarely in the sediment samples.

Living specimens of this group of Foraminifera occur from 30 fathoms to 600 fath-

oms. Their frequency distribution shows a marked maximum between 100 and 150 fathoms. They occur commonly at most stations deeper than 100 fathoms. Dead specimens are common over approximately the same depth range as living specimens.

GOËSELLA FLINTII Cushman
Plate 100, figures 10, 11

Goësella flintii CUSHMAN, 1936, Cushman Lab. Foram. Res., Spec. Publ. 6, p. 34, pl. 5, fig. 8.

Living specimens occur from 20 to 400 fathoms in Todos Santos Bay. The frequency (Text-fig. 21) shows a bimodal distribution which may indicate that it includes two closely related groups. The distribution of the dead specimens corresponds roughly with that of the living.

GYROIDINA ALTIFORMIS
R. E. & K. C. Stewart
Plate 103, figures 10, 11

Gyroidina soldanii var. *altiformis* R. E. & K. C. STEWART, 1930, Jour. Paleontology, vol. 4, no. 1, p. 67, pl. 9, figs. 2a–c.

No living specimens have been recorded from the area studied. Dead specimens occur rarely in the area of relict sediments in Todos Santos Bay and near the outcropping Pliocene strata on the continental shelf. It is believed that this species does not occur living in this area but represents a relict and/or residual species.

HÖGLUNDINA ELEGANS (d'Orbigny)
Plate 103, figures 5, 14

Rotalia (*Turbinulina*) *elegans* D'ORBIGNY, 1826, Ann. Sci. Nat., vol. 7, p. 276, no. 54.
Pulvinulina elegans Parker, JONES & BRADY, 1871 Ann. Mag. Nat. Hist., ser. 4, vol. 8, p. 174, pl. 13, fig. 142.
Epistomina elegans (d'Orbigny), CUSHMAN, 1931, U. S. Nat. Mus., Bull. 104, pt. 8, p. 65, pl. 13, fig. 6.

Living representatives of this species do not occur shallower than 400 fathoms in the area studied. They generally occur in low frequencies as can be seen from Text-figure 23. Dead specimens occur rarely in depths corresponding to the living distribution.

JADAMMINA POLYSTOMA
Bartenstein & Brand
Plate 101, figures 4, 5

Jadammina polystoma BARTENSTEIN & BRAND, 1938, Senckenbergiana, Bd. 20, p. 381, text. figs. 1a–c, 2a-l, 3.

Trochammina macrescens H. B. Brady, PHLEGER & WALTON, 1950, Am. Jour. Sci., vol. 248, p. 281, pl. 2, figs. 12, 13.

Living specimens of this species were recorded only from the marsh subfacies of the Estero de Punta Banda. Dead specimens occur in the channel subfacies but neither living nor dead specimens were found outside of the Estero de Punta Banda.

LABROSPIRA cf. L. ADVENA (Cushman)
Plate 99, figures 15–17

Haplophragmoides advena CUSHMAN, 1925, Contr. Cushman Lab. Foram. Res., vol. 1, pt. 2, p. 38, pl. 6, figs. 1a, b.

Living specimens of this species do not occur deeper than 50 fathoms in Todos Santos Bay. The frequency distribution shows a maximum between 40 and 50 fathoms. This distribution of the dead specimens roughly corresponds with that of the living specimens.

LABROSPIRA cf. L. COLUMBIENSIS
(Cushman)
Plate 99, figures 13, 18, 19

Haplophragmoides columbiense CUSHMAN, 1925, Contr. Cushman Lab. Foram. Res., vol. 1, pt. 2, p. 39, pl. 6, figs. 2a, b.

Living specimens of this species occur shallower than 300 fathoms in Todos Santos Bay. They occur most abundantly shallower than 100 fathoms with a maximum between 10 and 20 fathoms. Dead specimens are common in the samples in Todos Santos Bay and their distribution corresponds approximately with the living distribution.

LAGENIDAE

The species of this family were not differentiated and are included in one count. They have a limited distribution and do not appear to be significant ecological indicators.

LAMELLODISCORBIS sp.
Plate 102, figures 30, 31

This species, which occurs only near the head of the Estero de Punta Banda, is placed in *Lamellodiscorbis* Bermudez (1952) because the plate of the ventral side is simple, is restricted to the umbilical area, and has secondary apertures along the sutures. It differs from the closely related genus

Discorinopsis in the location of the plate and the secondary apertures.

This species was not found living in the area studied. It occurs dead at only one station in the Estero de Punta Banda, and was not found elsewhere in the area.

LOXOSTOMA PSEUDOBEYRICHI (Cushman)
Plate 102, figure 20

Bolivina pseudobeyrichi CUSHMAN, 1926, Contr. Cushman Lab. Foram. Res., vol. 2, pt. 2, p. 45; ——, 1927, Bull. Scripps Inst. Oceanog., Tech. ser., vol. 1, p. 156, pl. 3, fig. 7.

Living specimens were not found shoaler than 350 fathoms in the Todos Santos Bay area. The frequency distribution shows no marked maximum. This distribution of the dead specimens generally corresponds with that of the living specimens.

MILIAMMINA FUSCA (H. B. Brady)
Plate 100, figures 12, 13

Quinqueloculina fusca H. B. BRADY, 1870, Ann. Mag. Nat. Hist., ser. 4, vol. 6, p. 47, (286), pl. 11, figs. 2a–c.

Living specimens of this species occur abundantly in all the subfacies of the Estero de Punta Banda and rarely in a few samples from Todos Santos Bay. The distribution of the dead specimens of this species generally corresponds with that of the living specimens.

MILIOLIDAE

The Miliolidae were not differentiated, with the exception of *Quinqueloculina* sp., *Sigmoilina* cf. *S. miocenica*, and *Triloculina* sp. 1, sp. 2, and sp. 3. They are most abundant in the area of relict sediments around the Todos Santos Islands and include many species not represented by living forms.

NONIONELLA BASISPINATA
(Cushman & Moyer)
Plate 101, figures 16, 17

Nonion pizarrensis Berry var. *basispinata* CUSHMAN & MOYER, 1930, Contr. Cushman Lab. Foram. Res., vol. 6, p. 54, pl. 7 figs. 18a, b.

Living specimens of this species are restricted to depths shoaler than 150 fathoms in Todos Santos Bay. The frequency distribution shows a marked maximum between 40 and 50 fathoms. The species occurs most abundantly shoaler than 50 fathoms. Dead specimens are common in most of the bay samples and occur to depths of 380 fathoms.

NONIONELLA MIOCENICA STELLA
Cushman & Moyer
Plate 101, figures 13, 14

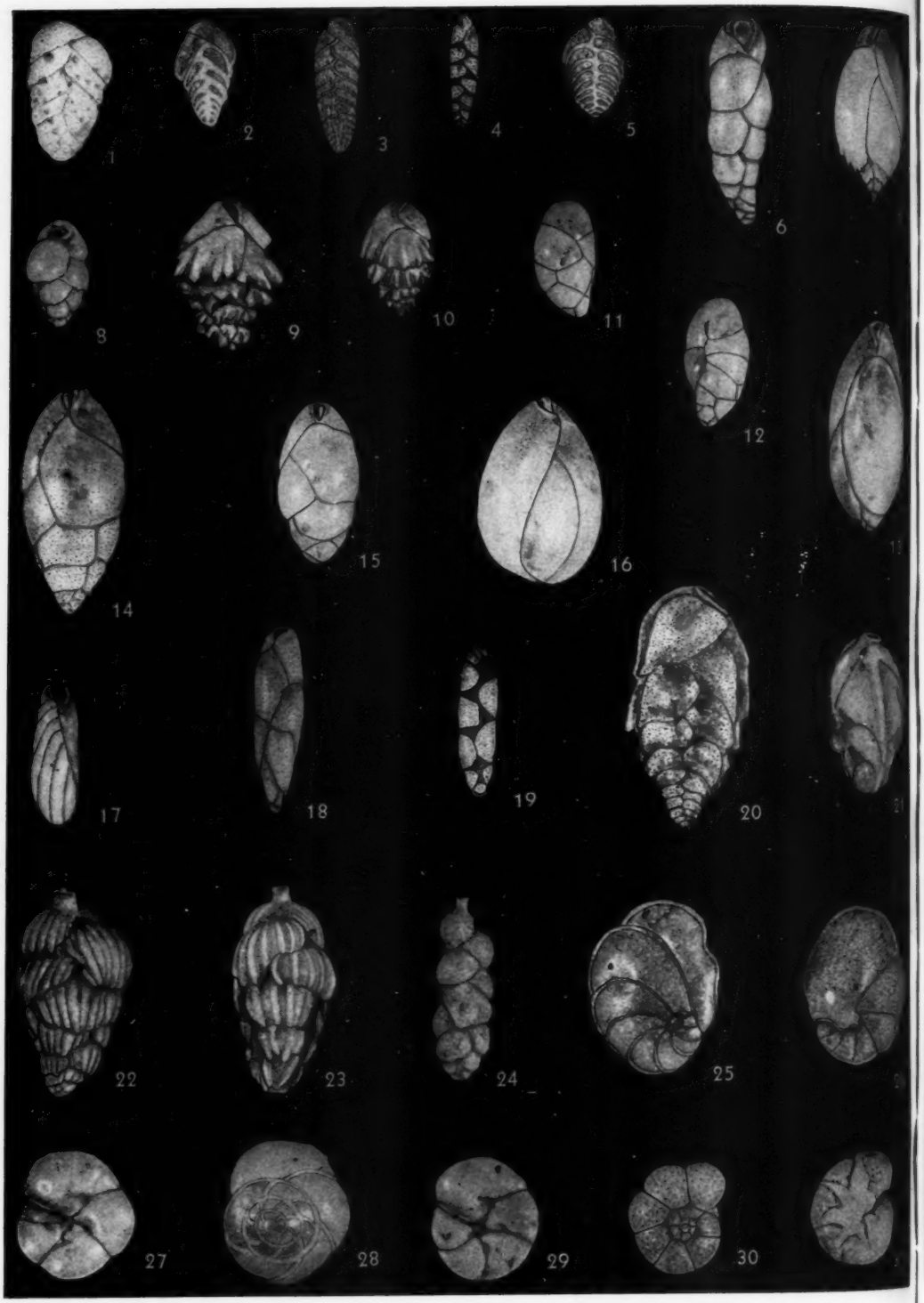
Nonionella miocenica Cushman var. *stella* CUSHMAN & MOYER, 1930, Contr. Cushman Lab. Foram. Res., vol. 6, p. 56, pl. 7, figs. 17a–c.

Living specimens of this species do not occur deeper than 250 fathoms in Todos Santos Bay. The frequency distribution (Text-fig. 20) shows a marked maximum between 30 and 40 fathoms, and the species occurs most abundantly between 10 and 100 fathoms. It is one of the most common living species encountered in this study. Dead specimens commonly occur over the same depth range as do the living specimens but are found to depths of 490 fathoms.

EXPLANATION OF PLATE 101

FIGS. *1–3—Arenoparrella mexicana* (Kornfeld). ×70.
4, 5—Jadammina polystoma Bartenstein & Brand. (4)×70; (5)×46.
6—Robulus sp. ×33.
7—Elphidium translucens Natland. ×46.
8, 9—Elphidium tumidum Natland. ×46.
10, 15—Elphidium sp. ×46.
11—Elphidium crispum (Linné). ×46.
12—Elphidium spinatum Cushman & Valentine. ×46.
13, 14—Nonionella miocenica stella Cushman & Moyer. ×46.
16, 17—Nonionella basispinata (Cushman & Moyer). ×46.
18–20—Nonionella sp. ×70.
21—Astrononion stellatum Cushman & Edwards. ×46.
22—Bifarina hancocki Cushman & McCulloch. ×46.
23—Bolivina vaughani Natland. ×70.
24, 25—Bolivina spissa Cushman. ×46.
26, 27—Bolivina argentea Cushman. ×33.

Walton, Living Foraminifera from Baja California



Walton, Living Foraminifera from Baja California

NONIONELLA sp.
Plate 101, figures 18–20

This species is very similar to *N. basiloba* (Cushman & McCulloch, 1940) but the last chamber extends down to the base of the periphery in long finger-like extensions.

The frequency distribution of the living specimens of this species shows a bimodal tendency. It occurs living from 30 to 400 fathoms but population peaks occur between 100 and 150 fathoms and 350 and 400 fathoms. This distribution suggests that two closely related species or varieties have been included in the population counts. Dead specimens are most common in water depths greater than 200 fathoms. This species is generally small and the young forms are difficult to distinguish from young representatives of *N. miocenica stella*. It is possible that the population maximum between 100 and 150 fathoms may include young forms of *N. miocenica stella*.

PLANORBULINA MEDITERRANENSIS d'Orbigny

Planorbulina mediterranensis D'ORBIGNY, 1826, Ann. Sci. Nat., vol. 7, p. 280, no. 2, pl. 14, figs. 4–6.

A few living specimens of this species were found attached to shell fragments and larger sediment particles in approximately 25 fathoms. The distribution of these commonly attached forms is controlled by the size of the sediment particles, and the species occurs only in the areas of coarser sediments. The distribution of the dead specimens corresponds with that of the living.

PLANULINA cf. P. ARIMINENSIS d'Orbigny
Plate 104, figures 27, 28

Planulina ariminensis D'ORBIGNY, 1826, Ann. Sci. Nat., vol. 7, no. 1, pl. 14, figs. 1–3 bis; Modeles, no. 49.

No living specimens of this species were found in the area studied. Dead specimens are most commonly associated with areas of relict and "fossil" sediments, and it is believed that they came from those sediments.

PLANULINA EXORNA
Phleger & Parker
Plate 104, figures 24, 25, 29, 30

Planulina exorna PHLEGER & PARKER, 1951, Geol. Soc. America, Mem. 46, pt. 2, p. 32, pl. 18, figs. 5a,b, 6a,b, 7a,b, 8a,b.

Planulina ariminensis GALLOWAY & WISSLER, 1927, Jour. Paleontology, vol. 1, p. 66, pl. 11, fig. 2.

Planulina ornata (d'Orbigny), CUSHMAN & VALENTINE [part], 1930, Contr. Dept. Geol., Stanford Univ., vol. 1, no. 1, p. 29, pl. 9, figs. 4a–c [not 2a–c].

EXPLANATION OF PLATE 102

FIGS. *1*—*Bolivina* cf. *B. pseudoplicata* Heron-Allen & Earland. ×70.
2—*Bolivina minuta* Natland. ×70.
3—*Bolivina striatella* Cushman. ×46.
4—*Bolivina pacifica* Cushman & McCulloch. ×46.
5—*Bolivina acuminata* Natland. ×46.
6—*Bulimina exilis tenuata* (Cushman). ×46.
7—*Bulimina spinifera* Cushman. ×46.
8—*Bulimina denudata* Cushman & Parker. ×46.
9—*Bulimina pagoda* Cushman. ×46.
10—*Bulimina subacuminata* Cushman & Stewart. ×46.
11, 12—*Robertina charlottensis* Cushman. ×46.
13, 16—*Globobulimina* spp. ×46.
14—*Bulimina subaffinis* Cushman. ×46.
15—*Bulimina affinis* d'Orbigny. ×25.
17—*Buliminella elegantissima* (d'Orbigny). ×70.
18—*Virgulina bramletti* Galloway & Morrey. ×33.
19—*Virgulina seminuda* Natland. ×46.
20—*Loxostoma pseudobeyrichi* (Cushman). ×46.
21—*Angulogerina carinata* Cushman. ×33.
22, 23—*Uvigerina peregrina* Cushman; variants. ×46.
24—*Uvigerina senticosa* Cushman. ×46.
25, 26—*Cancris auricula* (Fichtel & Moll). ×33.
27–29—*Discorbis* spp. ×46.
30, 31—*Lamellodiscorbis* sp. ×46.

Planulina depressa (d'Orbigny), NATLAND, 1933, Bull. Scripps Inst. Oceanog., Tech. ser., vol. 3, no. 10.
Planulina ornata (d'Orbigny) ? var., CUSHMAN & GRAY, 1946, Cushman Lab. Foram. Res., Spec. Publ. no. 19, p. 44, pl. 9, figs. 9–12.

This species was originally described from the northwest Gulf of Mexico, where it occurs in depths of less than 100 m. Specimens have been compared with type material and appear to be the same species. It is an extremely variable species, and many of the characteristics present in the young forms, e.g., the flat periphery and the thick prominent sutures, are lost in the adult specimens. The end members of this series are quite different, but an intergrading series can be found between the two.

Living specimens of this species are restricted to depths shallower than 100 fathoms in the Todos Santos Bay area. The frequency shows a maximum between 40 and 50 fathoms (Text-fig. 21), and the geographic distribution is characteristic of the marginal bay facies. Dead specimens have a wide distribution and occur as deep as 490 fathoms. The species is common in the Pliocene and Pleistocene of California and the deeper occurring specimens may be reworked.

POLYMORPHINIDAE

The Polymorphinidae were not differentiated in this study. The most abundant genus in the area of Todos Santos Bay is *Guttulina*.

PROTEONINA ATLANTICA Cushman
Plate 99, figure 1

Proteonina atlantica CUSHMAN, 1944, Cushman Lab. Foram. Res., Spec. Publ. 12, p. 5, pl. 1, fig. 4.

Living specimens occur over a wide depth range from 5 to 250 fathoms in Todos Santos Bay. The species is most common shallower than 100 fathoms, however, and its frequency distribution shows a maximum between 20 and 40 fathoms. The distribution of the dead specimens corresponds generally with that of the living specimens.

PROTEONINA sp.
Plate 99, figures 2, 3

This small species has been placed in the genus *Proteonina* because it has a single undivided chamber, the chamber wall is chitinous, and it is covered by small detrital particles, mostly mica. It is extremely fragile and seldom survives the drying process. Most of the dead counts were made from wet samples.

The frequency distribution of the living specimens (Text-fig. 23) is biomodal. This fact suggests that more than one closely related form has been included in the count. Also, a similar species is common in the marsh subfacies of the Estero de Punta Banda.

PULLENIA SALISBURYI
R. E. &. K. C. Stewart
Plate 104, figure 20

Pullenia salisburyi R. E. & K. C. STEWART, 1930, Jour. Paleontology, vol. 4, no. 1, p. 72, pl. 8, fig. 2.

Living specimens of this species are rare in Todos Santos Bay area but occur most commonly at approximately 200 fathoms. Dead specimens also are rare but occur to depths of 490 fathoms.

QUINQUELOCULINA sp.
Plate 100, figures 14, 19, 20

This species is a finely costate form with a single well-developed tooth. Living specimens are restricted to depths shallower than 20 fathoms and occur most abundantly in the 5 to 10 fathom depth range. Dead specimens are also restricted to this narrow depth range. A few living specimens were also found in the channel subfacies in the Estero de Punta Banda.

RECURVOIDES spp.
Plate 99, figures 12, 14

This group of specimens probably includes two closely related species. The shallower one is similar to *R. turbinatus* (H. B. Brady) from the Gulf of Maine and the Greenland Arctic (Phleger, 1952a).

The frequency distribution of the living specimens of these species is shown in Text-figure 22. It shows a bimodal distribution which would be characteristic of two superimposed distributions. There is one maximum shallower than 100 fathoms and one between 250 and 300 fathoms. Most of the dead specimens correspond with the shallower maximum (less than 100 fathoms).

REOPHAX AGGLUTINATUS Cushman
Plate 99, figure 10

Reophax agglutinatus CUSHMAN, 1913, Proc. U. S. Mus., vol. 44, p. 637, pl. 79, fig. 6; ——, 1920, U. S. Nat. Mus., Bull. 104, pt. 2, p. 9, pl. 2, figs. 4, 5; ——, 1921, U. S. Nat. Mus., Bull. 100, vol. 4, p. 73, pl. 14, figs. 2a, b; ——, 1932, U. S. Nat. Mus., Bull. 161, vol. 4, pt. 1, p. 4, pl. 1, figs. 1–3.

Very few living specimens were found in the area studied; they came from two stations in 96 and 125 fathoms. Dead specimens are much more common than living individuals and occur in both shallower and deeper water.

REOPHAX CURTUS Cushman
Plate 99, figure 9

Reophax curtus CUSHMAN, 1920, U. S. Nat. Mus., Bull. 104, pt. 2, pl. 2, figs. 2, 3.

Parker (1952) discusses this species and concludes that it includes *R. subfusiformis* Earland and *R. subfusiformis* Earland emend. Höglund, 1947.

Living specimens in the Todos Santos Bay area occur over a depth range between 10 and 50 fathoms with a marked maximum between 20 and 30 fathoms. The species is one of the most common forms in the middle bay facies. The distribution of dead specimens generally corresponds with that of living specimens.

REOPHAX GRACILIS (Kiaer)
Plate 99, figure 5

Nodulina gracilis KIAER, 1900, Rept. Nor. Fish Mar. Invest., vol. 1, no. 7, p. 24, 2 text figs.

Living specimens of this species have a rather wide distribution in this area; they range from 10 to 400 fathoms and are most common between 50 and 100 fathoms. Dead specimens appear to be most common shallower than 100 fathoms, but they are very fragile and may be lost in the drying process.

REOPHAX HORRIDA Cushman
Plate 99, figure 8

Reophax horrida CUSHMAN, 1912, Proc. U. S. Nat. Mus., vol. 42, pl. 28, figs. 3, 4.

This species has been reported from off Borneo in 890 and 569 fathoms. No other record in the Pacific is known to the author.

Living specimens range from 50 to 400 fathoms off Todos Santos Bay. The frequency distribution shows a marked maximum between 300 and 350 fathoms. The test of this species is very fragile and few dead specimens were found in the samples studied. The only dead specimens recorded are from 275 fathoms.

REOPHAX SCORPIURUS Montfort
Plate 99, figure 4

Reophax scorpiurus MONTFORT, 1808, Conch. Syst., vol. 1, p. 330.

Living specimens of this species range from 5 to 100 fathoms in the Todos Santos Bay area. Its frequency distribution shows a well-developed maximum between 20 and 40 fathoms (Text-fig. 21), and it is generally most abundant from 20 to 50 fathoms. It is one of the most abundant bay species, and its distribution is characteristic of the middle bay facies. The distribution of the dead specimens of this species corresponds generally with that of the living specimens.

REOPHAX sp. 1
Plate 99, figure 7

This small species is very fragile and generally does not survive drying. Its average length is approximately 0.5 to 0.7 mm., and the width of its largest chamber averages 0.1 to 0.2 mm. It commonly has 6 to 8 chambers composed of chitin, mica flakes, and small agglutinated Foraminifera shells.

Living specimens of this species are limited to depths greater than 300 fathoms and are most abundant between 350 and 400 fathoms.

REOPHAX sp. 2
Plate 99, figure 6

This small species does not occur outside of the Estero de Punta Banda. It contains about 7 or 8 chambers, is finely arenaceous, and has a round aperture. No living specimens of this species were found, but it is common in the channel subfacies of the estero. It ranges in length from 0.14 to 0.36 mm.

RHABDAMMINA cf. R. ABYSSORUM M. Sars

Rhabdammina abyssorum M. SARS, 1868, Forh. Selsk. Christiania, p. 248 [nomen nudum]; ——, 1868, in W. B. CARPENTER, Ann. Mag. Hist. Nat., ser. 4, vol. 4, p. 288.

No quantitative counts of this species were made. It occurs over a fairly restricted depth range from 19 to 38 fathoms.

ROBERTINA CHARLOTTENSIS (Cushman)
Plate 102, figures 11, 12

Cassidulina charlottensis CUSHMAN, 1925, Contr. Cushman Lab. Foram. Res., vol. 1, pt. 2, p. 41, pl. 6, figs. 6, 7.
Robertina charlottensis (Cushman), CUSHMAN, 1933, Cushman Lab. Foram. Res., Spec. Publ. 5, pl. 27, figs. 9a, b.

Living specimens of this species occur from 20 to 150 fathoms in the Todos Santos Bay area, and its frequency distribution shows a distinct maximum between 30 and 40 fathoms. Both living and dead specimens are rare in the area studied.

ROBULUS sp.
Plate 101, figure 6

This species only occurred rarely in the samples studied and not abundantly enough to warrant exact identification. No living specimens were found, and the dead specimens occur in the area of relict sediments or near outcrops of Pliocene strata. This species may be reworked from "fossil" faunas.

"ROTALIA" cf. "R." BECCARII (Linné)
Plate 103, figures 12, 13

Nautilus beccarii LINNÉ, 1758, Syst. Nat., ed. 10, p. 710, pl. 19, figs. 1a–c.

Variants of this species occur in shallow water all along the coast of New England and Venezuela, in the Gulf of Mexico, and in the San Francisco Bay and a shallow brackish lagoon south of Seal Beach, California.

Living specimens in the Todos Santos Bay area occur only in one station from the Estero de Punta Banda. Dead specimens are common in both the marsh and channel subfacies of the estero.

ROTALIA spp.
Plate 103, figures 18, 19, 24

?Rotalia versiformis BANDY, 1953, Jour. Paleontology, vol. 27, p. 179, pl. 22, figs. 5a–c.

This form was originally described from off San Diego, California, and it occurs in great abundance between 100 and 200 ft. *R. lomaensis* Bandy, described from the same suite of samples, was not differentiated and may be included in the author's count.

Living specimens of these species do not occur deeper than 50 fathoms in the Todos Santos Bay area, and their frequency distribution shows a maximum between 10 and 20 fathoms. Dead specimens of these species are very common in Todos Santos Bay and occur to depths of 230 fathoms. Dead specimens are generally more abundant in the areas of relict sediments.

RUDIGAUDRYINA INEPTA
Cushman & McCulloch
Plate 100, figure 6

Rudigaudryina inepta CUSHMAN & MCCULLOCH, 1939, Allan Hancock Pacific Exped., vol. 6, no. 1, p. 94, pl. 9, figs. 3–10.

No living specimens of this species were found in the area studied. Dead specimens

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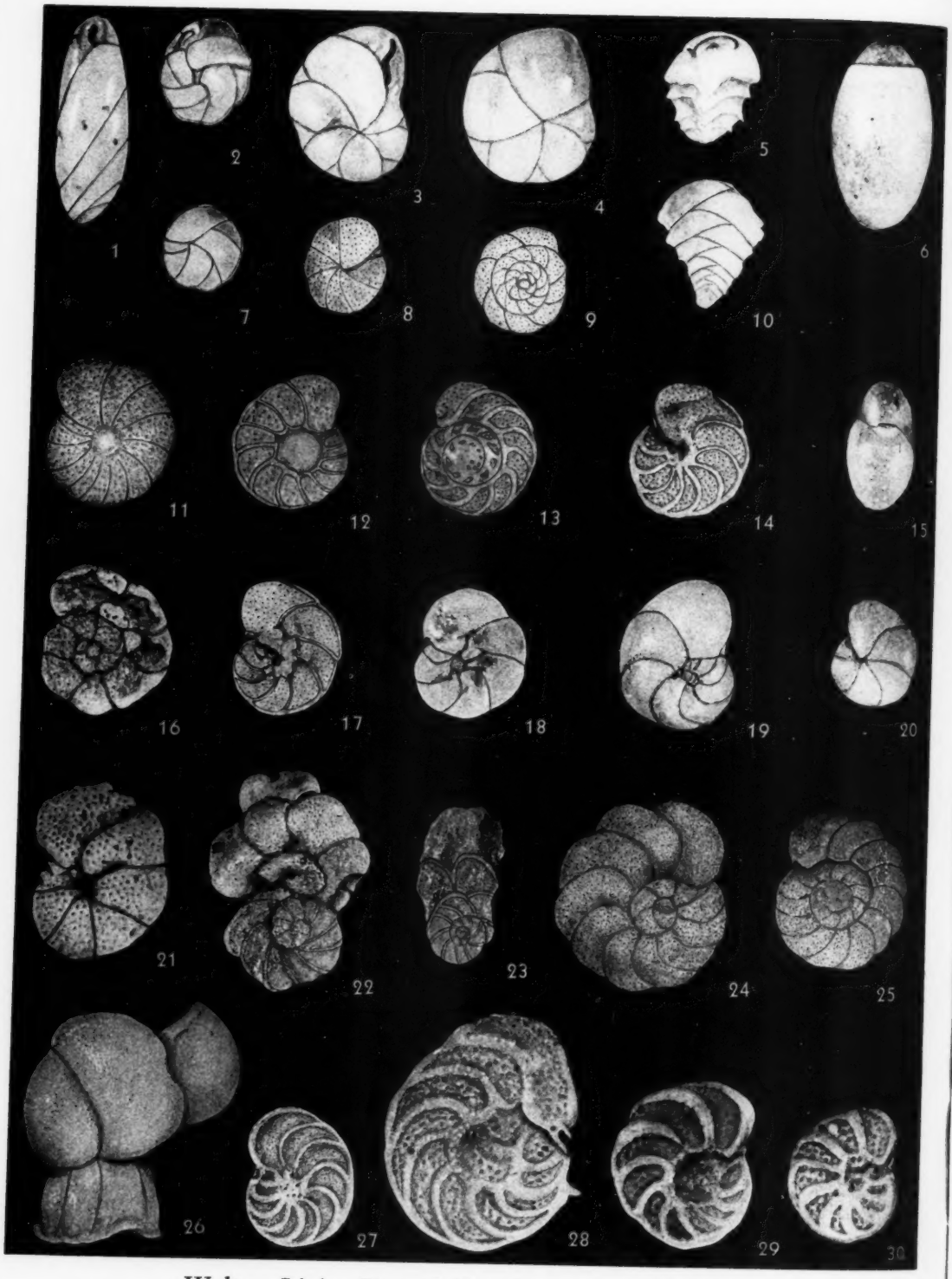
EXPLANATION OF PLATE 103

FIGS. *1, 2—Eponides subtenera* (Galloway & Wissler). ×46.
3, 4—Bucella frigida (Cushman). ×70.
5, 14—Höglundina elegans (d'Orbigny). ×46.
6, 7—Discorinopsis cf. *D. aguayoi* (Bermudez). ×46.
8, 9—Eponides cf. *E. repandus* (Fichtel & Moll). ×21.
10, 11—Gyroidina altiformis Stewart & Stewart. ×46.
12, 13—"Rotalia" cf. *"R." beccarii* (Linné). ×46.
15, 20—Valvulineria araucana (d'Orbigny). (15) ×46; (20) ×33.
16, 17—Valvulineria inaequalis (d'Orbigny). ×33.
18, 19, 24—Rotalia spp. ×46
21—Cassidulina subglobosa H. B. Brady. ×46.
22, 23—Epistominella smithi (Stewart & Stewart). ×46.
25—Cassidulina californica Cushman & Hughes. ×33.
26, 27—Cassidulina tortuosa Cushman & Hughes. ×46.
28, 29—Cassidulina delicata Cushman. ×70.
30—Cassidulina limbata Cushman & Hughes. ×46.

Walton, Living Foraminifera from Baja California



Walton, Living Foraminifera from Baja California

were found at only one station, in 39 fathoms.

RUPERTIA cf. R. STABILIS Wallich
Plate 104, figure 26

Rupertia stabilis WALLICH, 1877, Ann. Mag. Nat. Hist., ser. 4, vol. 19, p. 301, pl. 20.

No living specimens of this species were found in the area of Todos Santos Bay. It occurred dead in only one surface sample at 215 fathoms.

SIGMOILINA cf. S. MIOCENICA Cushman
Plate 100, figures 22, 23

Sigmoilina tenuis (Czjzek), CUSHMAN, 1929, Contr. Cushman Lab. Foram. Res., vol. 5, p. 81, pl. 12, figs. 12–14.
Sigmoilina miocenica CUSHMAN, 1946, Contr. Cushman Lab. Foram. Res., vol. 22, p. 33, figs. 19a–22.

This species appears to be more closely related to *S. miocenica* than to *S. tenuis*, and it differs from *S. tenuis* in that it has a shorter neck, broader test, and thick quinqueloculine portion of the test.

No living specimens of this species were found in the area of Todos Santos Bay. It occurs dead in the area of relict and fossil sediments and may indicate reworking of Pliocene strata.

TEXTULARIA cf. T. SCHENCKI Cushman & Valentine
Plate 100, figures 7, 8

Textularia schencki CUSHMAN & VALENTINE, 1930, Contr. Dept. Geol., Stanford Univ., vol. 1, no. 1, p. 8, pl. 1, figs. 3a,b.

Living specimens of this species occur in the Todos Santos Bay area from 10 to 100 fathoms. It is generally most abundant between 30 and 40 fathoms. Dead specimens are common over most of Todos Santos Bay and occur down to depths of 215 fathoms.

TEXTULARIA cf. T. EARLANDI Parker
Plate 100, figure 5

Textularia elegans LACROIX, 1932, [not *Plecanium elegans* Mantken], Bull. Inst. Ocean. Monaco. 591, p. 8, text figs. 4, 6.
Textularia tenuissima EARLAND, 1933, [not Hausler, 1881], *Discovery* Repts., vol. 7, p. 95, pl. 3, figs. 21–30.
Textularia earlandi PARKER, 1952, Bull. Mus. Comp. Zool., vol. 106, no. 10, p. 458 [footnote].

Living specimens of this species occur between 10 and 30 fathoms. Both living and dead specimens occur rarely in the samples from Todos Santos Bay but dead specimens are fairly common in the channel stations of the Estero de Punta Banda.

TRILOCULINA sp. 1
Plate 100, figures 16–18

This species is small, well rounded, and almost transparent, and it has a single well-developed tooth. It is common in the Todos Santos Bay samples and only occurs shallower than 50 fathoms. It is most abundant between 40 and 50 fathoms. The distribution of the dead specimens generally corresponds with that of the living specimens.

EXPLANATION OF PLATE 104

FIGS. *1*—*Cassidulinoides* sp. ×46.
2, 7—*Cassidulina laevigata* d'Orbigny. ×70.
3, 4—*Cassidulina* sp. ×46.
5, 10—*Ehrenbergina compressa* Cushman. ×46.
6, 15—*Chilostomella ovoidea* Reuss. ×46.
8, 9—*Cibicides spiralis* Natland. ×46.
11, 12—*Cibicides fletcheri* Galloway & Wissler. ×46.
13, 14—*Cibicides mckannai* Galloway & Wissler. ×46.
16, 21—*Cibicides gallowayi* Cushman & Valentine. (16) ×33; (21) ×46.
17–19—*Cibicidina nitidula* Bandy. ×33.
20—*Pullenia salisburyi* Stewart & Stewart. ×46.
22, 23—*Dyocibicides biserialis* Cushman & Valentine. ×33.
24, 25, 29, 30—*Planulina exorna* Phleger & Parker. (24, 25) ×33; (29, 30) ×46.
26—*Rupertia* cf. *R. stabilis* Wallich. ×33.
27, 28—*Planulina* cf. *P. ariminensis* d'Orbigny. (27) ×21; (28) ×46.

TRILOCULINA sp. 2
Plate 100, figures 15, 21

This species is rather flattened and elongate, and it is characterized by a very prominent single tooth. Living specimens are restricted to the marsh subfacies of the Estero de Punta Banda, but dead specimens occur in the channel subfacies as well.

TRILOCULINA sp. 3

This species was only found at one station in the Estero de Punta Banda. Both living and dead specimens were present.

TROCHAMMINA INFLATA (Montagu)
Plate 100, figures 27–29

Nautilus inflatus MONTAGU, 1808, Test. Brit. Supp., p. 81, pl. 18, fig. 3.

This species is one of the most common forms in the marsh subfacies of the Estero de Punta Banda. Living specimens are restricted to the marsh subfacies, but dead specimens are common in the channel stations. No specimens were found outside the Estero de Punta Banda.

TROCHAMMINA KELLETTAE Thalmann
Plate 100, figures 25, 26

Trochammina peruviana CUSHMAN & KELLET, 1929, Proc. U. S. Nat. Mus., vol. 75, art. 25, p. 4, pl. 1, figs. 8a,b.
Trochammina kellettae THALMANN, 1932, Eclog. Geol. Helv., vol. 25, no. 2, p. 313.

Living specimens of this species are restricted to depths shallower than 30 fathoms in Todos Santos Bay. It generally occurs in small percentages, and its frequency distribution shows no marked maximum. Dead specimens are common over most of Todos Santos Bay and occur to depths of 490 fathoms.

TROCHAMMINA PACIFICA Cushman
Plate 100, figures 30, 31

Trochammina pacifica CUSHMAN, 1925, Contr. Cushman Lab. Foram. Res., vol. 1, pt. 2, p. 39, pl. 6, figs. 3a–c.

Living specimens of this species occur at most depths shallower than 200 fathoms. It is one of the most widely distributed species in Todos Santos Bay and is most abundant shallower than 30 fathoms. Dead specimens are very common in the bay and occur generally over the same depth range as the living specimens.

UVIGERINA PEREGRINA
Cushman variants
Plate 102, figures 22, 23

Uvigerina peregrina Cushman var. *curticosta* (Cushman), CUSHMAN & MCCULLOCH, 1948, Allan Hancock Pacific Exped., vol. 6, no. 5, p. 266, pl. 34, fig. 2.
Uvigerina peregrina Cushman var. *disrupta* TODD, in CUSHMAN & MCCULLOCH, 1948, Allan Hancock Pacific Exped., vol. 6, no. 5, p. 267, p. 34, fig. 3.

Living specimens of these species occur from 20 to 600 fathoms in the Todos Santos Bay area. Although the varieties were not differentiated, it is obvious from their frequency distribution (fig. 22) that each has a fairly discrete depth range. *U. peregrina* var. *disrupta* is the deeper, occurring with its maximum frequency between 250 and 300 fathoms. *U. peregrina* var. *curticosta* apparently occurs shoaler with its frequency maximum between 50 and 100 fathoms. Dead specimens of these species occur over approximately the same depth range as the living specimens.

UVIGERINA SENTICOSA Cushman
Plate 102, figure 24

Uvigerina senticosa CUSHMAN, 1927, Bull. Scripps Inst. Oceanog., Tech. Ser., vol. 1, no. 10, p. 159, pl. 3, fig. 14.

No living specimens of this species were found in the area of Todos Santos Bay. Dead specimens occurred at some of the deeper stations in the vicinity of outcropping Pliocene sediments. It is believed that this species may not represent a living population.

VALVULINERIA ARAUCANA (d'Orbigny)
Plate 103, figures 15, 20

Rosalina araucana D'ORBIGNY, 1839, Voy. Amer. Merid., Foraminiferes, vol. 5, pt. 5, p. 44, pl. 6, figs. 16–18.
Valvulineria araucana (d'Orbigny), CUSHMAN, 1927, Bull. Scripps Inst. Oceanog., Tech. ser., vol. 1, no. 10, p. 160, pl. 4, figs. 7, 8.

Living specimens of this species occur over a depth range of 150 and 600 fathoms in Todos Santos Bay, and the frequency distribution (Text-fig. 22) shows a maximum between 200 and 250 fathoms. The distribution of dead specimens corresponds generally with that of the living specimens.

VALVULINERIA INAEQUALIS (d'Orbigny)
Plate 103, figures 16, 17

Valvulina inaequalis D'ORBIGNY, 1839, Voy. Amer. Merid., Foraminiferes, vol. 5, pt. 5, p. 48, pl. 7, figs. 10–12.
Valvulineria inaequalis (d'Orbigny), CUSHMAN, 1927, Bull. Scripps Inst. Oceanog., Tech. ser., vol. 1, no. 10, p. 161, pl. 4, figs. 9, 10.

Living specimens of this species occur deeper than 200 fathoms in Todos Santos Bay. It is rare in the samples studied and its frequency distribution shows no marked maximum.

VIRGULINA BRAMLETTI
Galloway & Morrey
Plate 102, figure 18

Virgulina bramletti GALLOWAY & MORREY, 1929, Bull. Amer. Paleontology, vol. 15, no. 55, p. 37, pl. 5, fig. 14.

Living specimens of this species occur from 100 to 600 fathoms in Todos Santos Bay, and it is most abundant between 300 and 400 fathoms. The distribution of the dead specimens corresponds generally with that of the living specimens.

VIRGULINA SEMINUDA Natland
Plate 102, figure 19

Virgulina seminuda NATLAND, 1938, Bull. Scripps Inst. Oceanog., Tech. ser., vol. 4, p. 145, pl. 5, fig. 12.

Living specimens of this species occur from 100 to 400 fathoms in the Todos Santos Bay area and are generally rare in the samples studied. The distribution of the dead specimens generally corresponds with that of the living specimens.

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CRETACEOUS MICROCRINOIDS FROM ENGLAND

RAYMOND E. PECK
University of Missouri, Columbia, Missouri

ABSTRACT—The types of *Roveacrinus alatus*, *R. communis*, and *R. rugosus*, all of Douglas, are redescribed and reillustrated. A new generic name, *Styracocrinus*, is proposed for those crinoids formerly referred to *Drepanocrinus peracutus* Peck, and the new subfamily name Styracocrininae is substituted for Drepanocrininae. Three new species are established and are referred to the genera *Roveacrinus*, *Discocrinus*, and *Orthogonocrinus*.

European Roveacrinidae range from the Cenomanian to the Danian (i.e., through the Upper Cretaceous) but only a few specimens have been found in rocks younger than Santonian. Three species, *S. peracutus* Peck, *O. apertus* Peck, and *R. alatus* Douglas are known from both Europe and the United States.

INTRODUCTION AND ACKNOWLEDGMENTS

ALTHOUGH the occurrence of small pelagic crinoids in Cretaceous rocks has been known for almost fifty years, they have escaped the attention of most collectors. The calyces, from about one to four millimeters in length, are too small to be noticed by most collectors of megafossils, and too large to be found in the screenings most often studied for microfossils. Deliberate search for microcrinoids in the Lower Cretaceous rocks bordering the west Gulf Coastal Plain of the United States or in the Upper Cretaceous rocks of England, France, and Germany is likely to be rewarded by an abundance of specimens.

In so far as known the first collector of these small crinoids was Mr. A. W. Rowe, who obtained collections from Seaford Head, Sussex, England. Mr. Rowe submitted his collections to J. A. Douglas who published the first record of them in the Geological Magazine in 1908 under the generic name *Roveacrinus*. Ten years later Jaekel, evidently unaware of the paper by Douglas, described similar forms from the Cretaceous of Germany under the generic name *Drepanocrinus*. In 1932 Sieverts published an excellent and detailed paper on *Drepanocrinus sessilis* Jaekel. Immediately after the publication of this paper, Sieverts discovered the descriptions of Douglas and published another paper (1932) pointing out that *Drepanocrinus* Jaekel and *Roveacrinus* Douglas are synonyms. In 1943 Sieverts published more information on *Roveacrinus* Douglas and referred the genus to the family Saccocomidae d'Orbigny (emended Sieverts).

Cretaceous Roveacrinidae in the United States were first described by Peck in 1943. A large and complete collection from the Lower Cretaceous of Texas had been made available by Drs. Alfred and Helen Loeblich, and it was possible to record the evolutionary history and stratigraphic range of these small crinoids in considerable detail.

In 1950–51, while I was studying in France on a Fulbright award, Professor Pierre Marie generously presented me with some microcrinoids from the Turonian of the western part of the Paris Basin. These specimens have been helpful in the preparation of this paper, and details of the collection will be published elsewhere. Dr. Hertha Sieverts-Doreck of Stuttgart, with whom I had a pleasant and profitable visit, presented me with specimens of *Roveacrinus sessilis* (Jaekel) and *R. westfalicus* Sieverts from the Cretaceous of Germany.

After completing my work in France, I took the opportunity to study the Cretaceous microcrinoids in the British Museum (Natural History). Dr. W. N. Edwards, Keeper of the Geology Department, and Dr. Leslie Bairstow, Keeper of the echinoderm collections, generously made available working space in the Museum and placed at my disposal the microcrinoids collected by Mr. A. W. Rowe, Dr. F. A. Bather, and others. In the limited time available, camera-lucida drawings were made of the type specimens of Douglas and notes were taken for later reference. It was evident at that time that not only were the type speci-

mens of Douglas worthy of redescription and reillustration, but that the entire collection was a valuable one and merited description and study. I am grateful to Dr. Edwards and Dr. Bairstow for granting the loan of all Roveacrinidae, other than types, for study and comparison with the types from the Texas Cretaceous.

The drawings and the retouched photographs comprising the illustrations have been carefully and skillfully prepared by Mrs. Vaona Hedrick Peck. Dr. M. G. Mehl has read the manuscript and contributed many valuable suggestions.

MORPHOLOGY

The general morphology and evolutionary history of the Roveacrinidae have been discussed in some detail by Sieverts (1932, 1943) and by Peck (1943, 1948). The calyces consist of five radial plates only (Styracocrininae) or five radial plates the proximal ends of which are overgrown by a bulbous noncirriferous centrodorsal (Roveacrininae). The centrodorsal is not divided and the interradial sutures on specimens belonging to the Roveacrininae terminate proximally at the upper limit of the centrodorsal. Crinoids of this family are unique in possessing two cavities, a calyx cavity and a centrodorsal cavity, the two separated by a horizontal partition. Previous to the present study there has been no evidence concerning the origin of either the centrodorsal or the horizontal partition. The study of the collections in the British Museum Geological Department provide information bearing on these questions but the evidence is not conclusive.

A representative of *Roveacrinus communis* (E-25712) shows clearly (Pl. 105, fig. 9) a sutural division of the horizontal partition into five quadrangular units that are interradial in position and may be interpreted as basal plates. If these do represent basals the horizontal partition and the radials comprise the normal crinoid cup and the centrodorsal is a separate growth that is probably analogous to the centrodorsal of the comatulids.

Another possible interpretation of the morphology is based on the holotype of *Roveacrinus bairstowi*, n. sp. (Pl. 106, figs. 1, 3, 6) and *Roveacrinus euglypheus* Peck. On the holotype of *R. bairstowi* there seems to be a sutural separation of the centrodorsal into five plates of unequal size. No other representative of this species shows any indication of basal sutures.

The ridge ornamentation of *Roveacrinus euglypheus* Peck (1943) follows the same pattern as the "sutures" on *R. bairstowi* and was at first thought to represent a division of the centrodorsal into basals. This character is persistent on specimens of *R. euglypheus* and study of several specimens led Peck (1943, p. 469) to the conclusion that the ridges represented only ornamentation and not sutures. It was found that crushed specimens separate readily along the interradial sutures but below the radials there is no regular line of weakness indicating sutures. It would be unusual to have basal sutures present in Cenomanian and Coniacian specimens when hundreds of representatives of the Roveacrininae from the Albian fail to show such structures.

The origin of the centrodorsal in the Roveacrininae is not clearly understood. It is a separate structure that grows over the basals (?) and the proximal ends of the radials. The interradial sutures end at the top of the centrodorsal and the ornamentation of the centrodorsal is largely independent of that on the radials. The radial facet supports originate on the radials and, in many species, extend over and beyond the centrodorsal. That this support is an extension of the radials is clearly shown by the continuation of the ornamentation for the full length of the radial facet support.

The writer believes that the centrodorsal and centrodorsal cavity originated through the growth of subjacent stem joints to surround the immediately overlying joint or joints, to cover the basals, and the proximal ends of the radials. Subsequently, adjacent stem joints were resorbed, leaving the centrodorsal cavity. Proximal extensions of the radial facet supports grew down over the centrodorsal and firmly cemented it to the aboral end of the calyx. In the Styracocrininae there was no excessive growth of a stem joint to form a centrodorsal but the radials extended proximally over the basals, the basals forming the horizontal partition. This speculation is, of course, based on the interpretation that the horizontal partition represents basals.

LIFE HABITS

All students of the Roveacrinidae are in agreement that they were planktonic organisms. Peck (1943, p. 453) described them as "planktonic, floating passively, mouth down and arms pendant, driven along with the current with little if any power to determine their direction of movement." I am grateful to Professor Torsten Gislen for pointing out (personal communication, Feb. 7, 1950) that it would be difficult for these crinoids to catch sinking particles of food if they floated with the mouth down, and that the calcareous dorsal parts would be appreciably heavier than the fleshy ventral parts, which would argue for a mouth-up living position. Professor Gislen also called attention to the fact that the central canals of the Roveacrinidae are comparatively large, indicating a large nerve cord and extremely flexible arms. The strongly corrugated processes on the brachials and on the sides of the radials were probably muscle attachments which also indicate flexibility of the arms.

STRATIGRAPHIC DISTRIBUTION

In North America, the Roveacrinidae range through much of the upper Comanche series, i.e., from the Goodland limestone (middle Albian) to the Grayson formation (lower Cenomanian); and, if *Somphocrinus mexicanus* is correctly referred to this family, the range extends to the Karnian (Upper Triassic). In Europe, the known distribution is within the Upper Cretaceous (Cenomanian to Danian), although the majority of the collections have come from rocks of Cenomanian, Coniacian, and Santonian ages.

The species with the longest range and the most cosmopolitan distribution is *Styracocrinus peracutus* (Peck), known from the Comanchean Cretaceous of Texas and the Upper Cretaceous of Europe. This form is the only representative of the Roveacrinidae younger than Santonian. *Orthogonocrinus apertus* Peck and *Roveacrinus alatus* Douglas are also represented in Europe and the United States. The genus *Discocrinus* is represented by a different species in Europe than in the United States, and the genera *Plutocrinus* and *Poecilocrinus* are well represented in the United States but have not been recorded from Europe. *Roveacrinus* Douglas is common on both continents but the only species recognized on both sides of the Atlantic is *R. alatus* Douglas and this species is never abundant. By far the most common species in Europe is *R. communis* Douglas which is well represented in England, France, and Germany.

SYSTEMATIC PALEONTOLOGY

Family ROVEACRINIDAE Peck, 1943

Small stemless pelagic Articulata with calyces composed of five radials only, or five radials with ornamented noncirriferous centrodorsals. The calyx cavity is divided into two parts, a body cavity and a centrodorsal cavity, by a horizontal partition. Arms five or ten, the division, when present, on the second brachial.

Distribution.—Triassic (Karnian) of Mexico (?), Cretaceous of Europe and North America.

In 1948 Peck described a new genus and species, *Somphocrinus mexicanus*, of crinoids from the Karnian of Mexico and referred them to the Roveacrinidae. In that paper Peck (1948, p. 81) redefined the family Roveacrinidae, placing greater emphasis on the construction of the arms, and excluding the genera *Styracocrinus* [*Drepanocrinus*, as interpreted by Peck] and *Orthogonocrinus* from the family. The present study of the Cretaceous microcrinoids in the British Museum and the opportunity of studying specimens from Germany and France has convinced me that the presence of the horizontal partitions dividing the calyces into body and centrodorsal cavities is a more valid indication of relationship than is the development of the arms. It is here proposed to re-establish, with the slight modifications outlined above, the original conception of the family Roveacrinidae with the division into two subfamilies, the Styracocrininae, new name, and the Roveacrininae Peck, 1943. The genus *Somphocrinus* is closely related to the Roveacrinidae and probably belongs in the subfamily Roveacrininae.

Subfamily STYRACOCRININAE Peck, n. name

Roveacrininidae with compact calyx walls composed of five radial plates of equal size. Arms slender and probably undivided, not known beyond the third brachial.

The new subfamily name is proposed to replace the name Drepanocrininae Peck, 1943. As indicated below, Peck misinterpreted the genus *Drepanocrinus* and the crinoids referred to this genus as *D. peracutus* Peck are here referred to the new genus, *Styracocrinus*.

Genus STYRACOCRINUS[1] Peck, n. gen.

Type species.—Drepancorinus peracutus Peck, 1943

Distribution.—Middle Albian to lower Cenomanian (Goodland to Grayson) of North America, Cenomanian to Danian of England.

Diagnosis.—"Small, elongate, slender crinoid crowns with slender undivided arms and conical calyces composed of five elongate, triangular radials. Radial facets occupying most of the distal surfaces of the radials, triangular or semicircular in shape, sloping outward, the angle from horizontal a little greater outside than inside the transverse ridge. Dorsal ligament fossae and inarticular ligament fossae well developed, muscular fossae narrow, and partially excavated in sides of interfacet processes. Arms simple, not branching, the distal surface of Br_1 sloping inward and joined to Br_2 by cryptosynarthy. Calyx smooth and compact, not coarsely porous. Some specimens covered with fine network of ridges." Peck, 1943.

The genus *Drepanocrinus* was described by Jaekel in 1918 and redescribed and discussed by Sieverts in 1932. Later in the same year Sieverts (1932b) considered the name *Drepanocrinus* a synonym of *Roveacrinus* Douglas. Peck (1943) disagreed with the interpretation given by Sieverts and recognized *Drepanocrinus* as a valid genus. Study of the type specimens of *Roveacrinus alatus* Douglas in the British Museum (Natural History) and of specimens of *Drepanocrinus sessilis* Jaekel, identified by Sieverts, has resolved any doubt concerning the correctness of the interpretation by Sieverts. *Drepanocrinus* Jaekel is a synonym of *Roveacrinus* Douglas and the new name *Styracocrinus* is proposed for those crinoids referred to *Drepanocrinus* by Peck (1943).

STYRACOCRINUS PERACUTUS (Peck), 1943
Plate 106, figures 10–12

Drepanocrinus peracutus PECK, 1943, Jour. Paleontology, vol. 17, p. 463, pl. 76, figs. 9–22, 26, 28.

Comparison of the specimens from England with those of the type material from Texas shows no differences that would justify the introduction of another specific name. In both collections, specimens differ in size, in prominence or radial ridges, in degree of flatness of the radial facets, and in other minor characters, but these differences do not appear to be consistent enough to merit specific distinction.

The species may be easily recognized by the slender, spike-like form; the elongate, somewhat triangular radial facets; and the extension of the radial sutures to the proximal end of the calyx.

Types.—Holotype E-23-3, University of Missouri; paratypes, 1002, 1003, U. S. National Museum; figured specimens E-45669, E-45670, E-15510, British Museum Geological Department.

Occurrence.—Danian chalk detritus, Charing Kent, and Cenomanian chalk marl, ten feet above the base, north of Cambridge, England; common from Goodland to the Grayson (Albian to lower Cenomanian) in Texas.

Genus ORTHOGONOCRINUS Peck, 1943
ORTHOGONOCRINUS APERTUS Peck
Plate 106, figures 7–9

Orthogonocrinus apertus PECK, 1943 Jour. Paleontology, vol. 17, p. 464, pl. 76, figures 2–8.

The British Museum (Natural History) collection contains only five specimens of this species. They vary from the Texas forms in having a heavier reticulate ornamentation and in tapering more rapidly proximally. In all other details they closely resemble the North American forms and, I believe, should not be differentiated specifically.

Types.—Holotype E-21-5, University of Missouri; paratypes E-22-1-4, University of Missouri, numbers 1000, 1001, U. S. National Museum; figured specimens E-15507, E-45869–70, British Museum (Natural History) Geological Department.

Occurrence.—Duck Creek to Grayson formations (Albian to lower Cenomanian) in North America; Cenomanian chalk, 10 feet above base, near Cambridge, England.

ORTHOGONOCRINUS EXCAVATUS Peck, n. sp.
Plate 106, figures 16–17

Calyx ranging up to 2 mm. in diameter at

[1] στύραξ—spike.

the summit, tapering rapidly proximally, strongly pentagonal in end view, with large and well developed arm facets separated proximally by deep indentations in the calyx wall.

Radial facets large, approximately horizontal distal to the transverse ridge, proximal portion deeply excavated. Central canals fairly large, located on the periphery of the summit. Interarticular ligament fossae large, excavated below the general surface of the facet, elongate parallel to the interfacet processes, bordered distally and laterally along most of their length by prominent crescentric ridges that connect the interfacet processes. Muscular fossae smaller than interarticular ligament fossae, elongate, and deeply sunken between crescentric ridge and interfacet processes. Dorsal ligament fossae very large, deeply excavated, rounded and bordered by a raised rim. Ligament pit about the size of the central canal and deeply sunken.

Calyx cavity small, the summit opening less than one-third the diameter of the summit. Internal horizontal partition located at the proximal end of arm facets and the calyx wall thin and delicate below this plane.

The specific name is in reference to the deep excavations between the arm facets.

Types.—Holotype E-15635; paratype E-15636; British Museum (Natural History) Geological Department.

Occurrence.—Coniacian (*Micraster cortestudinarium* zone), Slines Oak Pit, Worms Heath, Waldingham, Surrey, and Hodgen Bottom (Dowding Castle) Tadsworth, Surrey, England.

Discussion.—*O. excavatus* is the second species of this genus to be defined. It is readily differentiated from *O. apertus* by the rapid proximal taper of the calyx, the deep indentations between the proximal parts of the arm facets, and by the large dorsal ligament fossae.

O. excavatus is not a common form in the collections of the British Museum, only seven specimens having been observed and all of them from the same zone and from the same general location.

Present records indicate that *O. excavatus* is a younger species than *O. apertus* and probably developed from it.

Subfamily ROVEACRININAE Peck, 1943

"Roveacrinidae with calyces composed of radials and noncirriferous centrodorsals. Skeletal structure coarsely porous. Arms five or ten, the division, when present, on Br_2." Peck, 1943.

Genus ROVEACRINUS Douglas, 1908, emend. Sieverts, 1933; Peck, 1942

"Small to medium size Roveacrininae with radial ornamentation consisting primarily of five flanges connecting the proximal centers of the arm facets with the aboral pole. The arm facets are small, semi-circular, about as wide as long and separated by a distance equal to their own width. Arms probably 10, branching on $BrBr_2$, ornamentation similar to that of the calyx. $BrBr_1$ and $BrBr_2$ joined by cryptosynarthy." Peck, 1943.

ROVEACRINUS ALATUS Douglas, 1908
Plate 105, figures 15–16

Roveacrinus alata DOUGLAS, 1908, Geol. Mag., Decade 5, vol. 5, p. 358, pl. 17, figs. 1, 2.
Drepanocrinus sessilis SIEVERTS, 1932, Preuss, geol. Landesanstalt Jahrb., vol. 53, fig. 6.
Roveacrinus pentagonus PECK, 1943, Jour. Paleontology, vol. 17, p. 467, pl. 72, fig. 12, pl. 73, figs. 1–5, 7.

Calyx of medium size for the family, attaining maximum dimensions of about 2.5 mm. in height and 2 mm. in width. The radial facet supports consist of wide thin vertical flanges that extend below the aboral end of the centrodorsal. The flanges may be simple and undivided, as on the holotype; thickened distally as spine bases; or possessing small lateral flanges branching off of the upper part. The radial facets are small and semicircular in shape. The surface is smooth or covered with a network of ridges.

Types.—Holotype E-45704, figured specimen E-45840, British Museum (Natural History) Geological Department.

Occurrence.—Coniacian (*Micraster cortestudinarium* zone), Seaford Head, Sussex; Cenomanian chalk near Cambridge, England; Upper Cretaceous, Germany; lower Cenomanian, North America.

Discussion.—The holotype of *R. alatus* was not labeled by either Douglas or Rowe, but there is only one complete calyx of this species in the A. W. Rowe collection from Seaford Head, Sussex, at the British Museum. That specimen was selected and labelled as the holotype by Dr. Leslie Bairstow, Keeper of the echinoderm collections of the Museum. Another representative of the species in the A. W. Rowe collection is

broken horizontally across the centrodorsal.

The holotype was studied at the British Museum in May of 1951 and a camera lucida drawing (Pl. 105, fig. 15) was made by Mrs. Vaona Peck. The above description is based on notes taken while examining the holotype, on subsequent study of materials loaned by the Museum, and on a re-study of the types of *R. pentagonus* Peck from the Grayson formation in Texas.

The holotype of *R. alatus* Douglas represents a comparatively rare development in the Roveacrininae in that the radial facet supports are wide thin flanges extending below the main body of the crinoid. It closely resembles the form illustrated by Peck (1943, pl. 72, fig. 12) from the Grayson of Texas. Other calyces from the Cretaceous of England and from the Grayson of Texas possess the flange with various modifications as described in the specific diagnosis. Most of these forms are twisted and broken but the possession of the flanges and the small radial facets indicate clearly that they are closely related to the form selected as the type. Most of the modifications of *R. pantagonus* illustrated by Peck in 1943 have been recognized in the study of the material in the British Museum.

The description Douglas gave of the species is good but he did take liberties in restoration for his illustrations. As the holotype now exists it has only one long interradial process and two short ones. In fairness to Douglas, it is quite possible that some of the processes have been broken since he studied the specimen.

In 1932 Sieverts referred crinoids from the Cretaceous of Germany to *R. alatus* Douglas. Her figures show strong radial spines and her description states that the cup is covered with a network of coarse ridges. Although the holotype and paratype from Seaford Head show no evidence of developing spines and ridges, it is probable that the material described by Sieverts should be referred to this species.

ROVEACRINUS COMMUNIS Douglas
Plate 105, figures 1–14

Roveacrinus communis DOUGLAS, 1908, Geol. Mag., Decade 5, vol. 5, p. 359, pl. 17, figs. 3, 4.
Drepanocrinus sessilis JAEKEL, 1918, Paleont. Zeitschrift, vol. 3, p. 72, figs. 66A-G.
Drepanocrinus sessilis SIEVERTS, 1932, Preuss. geol. Landesanstalt, Jahr., vol. 53, pp. 599–608, figs. 1–5, 7–15, 17.
Roveacrinus westfalicus SIEVERTS, 1932, Centralb. Mineralogie, Abt. B., p. 56, figs. 1, 2.
Roveacrinus sessilis SIEVERTS, 1932, Centralb. Mineralogie, Abt. B, p. 58.

Elongate, conical calyces with an average height of about 2 mm., and a maximum overall height of slightly less than 4 mm. Radial facet supports well developed; either rounded, thin and platy, or thick and flattened on top; bifurcating distally just below the arm facets on some specimens. The supports terminate just below the aboral end of the calyx as short, pointed projections, or thicken proximally and project well beyond the aboral end of the calyx as heavy spines. If all five of the supports project aborally they coalesce to form a single spike-like projection. On many specimens not more than three or as few as one of the supports develop spines, the other supports ending proximally as points just below the aboral end of the calyx. The aboral end of the calyx is pointed. The centrodorsal is not prominent but is represented by interradial swellings between the

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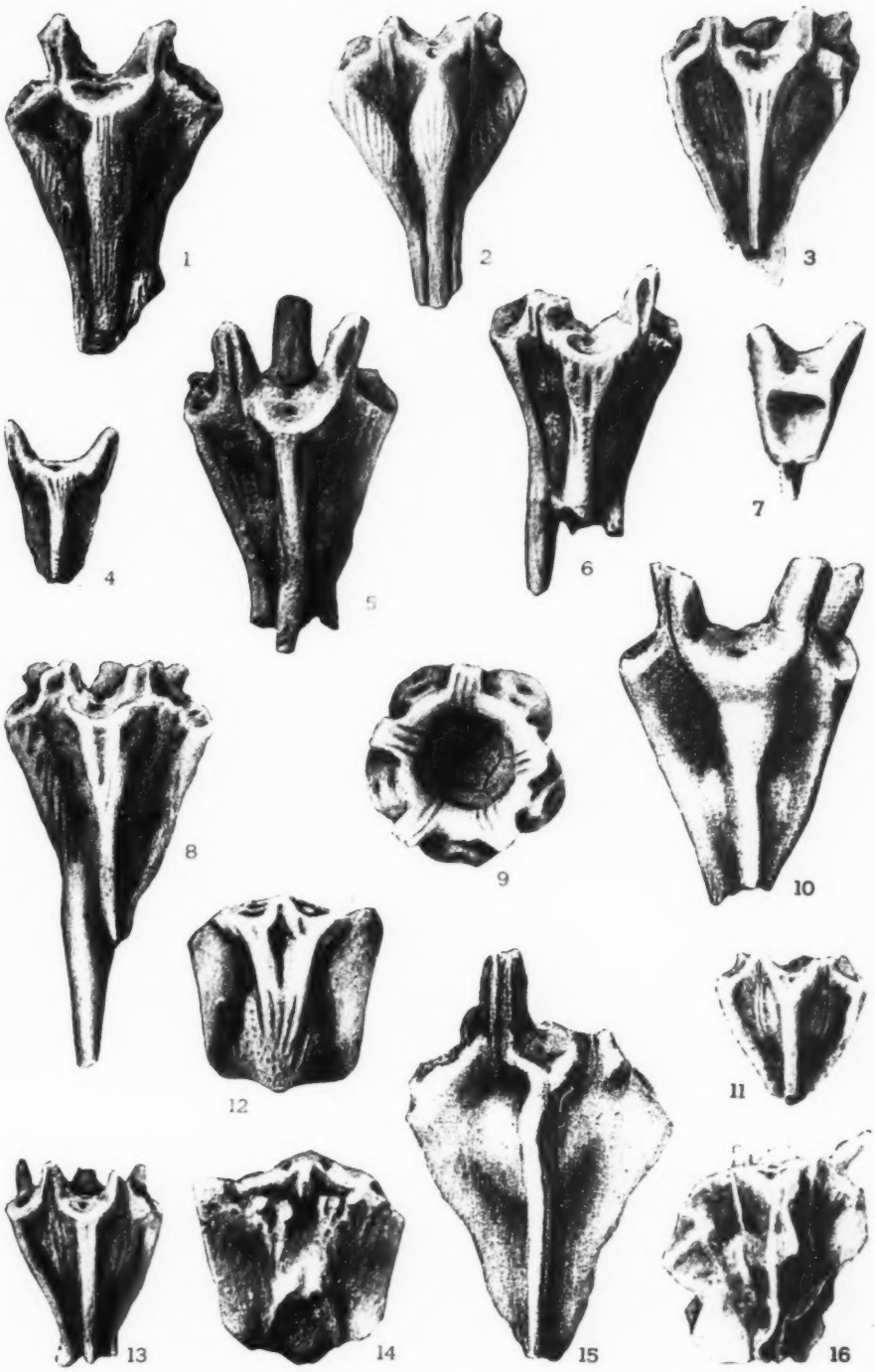
EXPLANATION OF PLATE 105

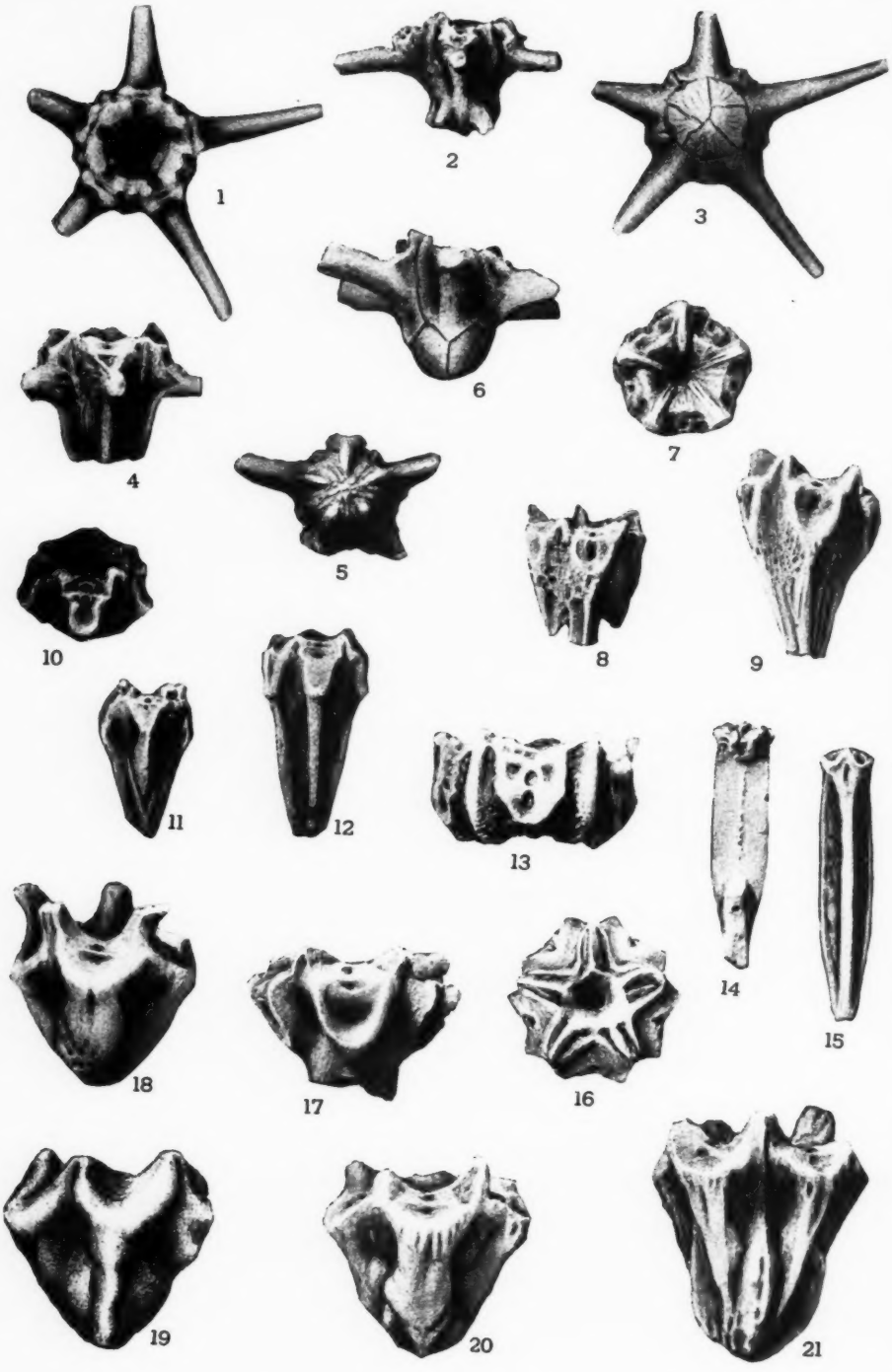
All figures ×16. Except where noted all specimens deposited in the Geological Department of the British Museum (Natural History).

FIGS. *1–14—Roveacrinus communis* Douglas. 1, "*R. sessilis*" from Germany, Univ. Missouri E-45-1; 2,3,5,6,8,11,13, lateral views showing growth stages and variations in ornamentation, E-15036, E-25707, E-25708, E-25709, E-25705, E-25706; 4,7, exterior and interior views of isolated radials E-24532, E-24533; 9, oral view showing division of horizontal partition into plates, E-25712; 10, lateral view of lectotype, E-25705; 12,14, exterior and interior views of primaxils probably belonging to this species, E-24530, E-24531.

15,16—Roveacrinus alatus Douglas. 15, lateral view of holotype, E-45704; 16, lateral view of specimen with facet supports thickened distally, E-45840.



Peck, Cretaceous microcrinoids from England



Peck, Cretaceous microcrinoids from England

proximal portions of the radial facet supports.

The ornamentation of the calyces consists of fine to fairly heavy ridges paralleling the interradial sutures. These ridges continue to the aboral end of the calyx on the radial facet supports, ending on the body of the radial at the contact with the centrodorsal, the centrodorsal longitudinal ridges being independent of those on the radials. On some specimens the oral end of the calyx is reticulate. The sides of adjoining radials are raised to form a ridge along the interradial sutures, the ridge ending at the base of the radials or bifurcating and extending as converging ridges toward the proximal end of the centrodorsal.

Radial facets fairly large, occupying most of the distal surfaces of the radials, semicircular to subangular in shape, truncated proximally on those specimens with flattened or bifurcating radial facet supports. Central canal large, located on the inner border of the facet and extending from the inner margin to the transverse ridge. Interarticular ligament fossae small and located along the sides of the central canal. Dorsal ligament fossae large, occupying approximately half of the radial facet, ligament pit deep.

Calyx cavity fairly large, terminated proximally by a thin partition separating the calyx cavity from the centrodorsal cavity, the partition formed by five quadrangular plates in an interradial position. These plates may represent the basals.

Immature specimens short, conical, with narrow radial facet supports that continue over the small centrodorsals. Most immature specimens have a rounded opening at the aboral end of the calyx. The openings are irregular and show no evidence of stem attachment. It cannot be determined whether the openings are the results of breakage or the failure of this portion to calcify.

Brachials not definitely identified but primaxils probably belonging to this species are large and flat with a longitudinal ridge bifurcating to produce single ridges on the secundibrachs. These brachials have lateral flanges that were probably in contact on the living crinoid to form a closed cavity.

Types.—Lectotype E-45705, figured specimens E-15036, E-24532–33, E-24530–31, E-25708–09, E-25705–7, British Museum (Nat. Hist.)

Occurrence.—Common and widely distributed from the *Rhynchonella cuvieri* zone (Turonian) through the *Micraster coranguium* zone (Santonian). The largest number of specimens are from the *Micraster cortestudinarium* zone (Coniacian) of England; upper Cenomanian of Germany; upper Cenomanian to Coniacian of France.

Discussion.—In the A. W. Rowe collection from Seaford Head, Sussex, at the British Museum Geological Department there are 39 specimens that are referable to this species. These calyces were probably all available to Douglas when the specific description was written and can therefore be considered types. One specimen from among the 39 (E-45705) has been chosen as the lectotype and is illustrated in this paper

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EXPLANATION OF PLATE 106

All figures ×16. All specimens in Geological Department of British Museum (Natural History).

FIGS. *1–6—Roveacrinus bairstowi* Peck, n. sp., 1,3,6, oral, aboral, and lateral views of holotype, E-25701; 2,4, lateral views of paratypes showing variation in ornamentation, E-25702, E-15633; 5, aboral view of paratype, E-24514.

7–9—Orthogonocrinus apertus Peck. Oral and two lateral views, E-45869, E-45870, E-15507.

10–12—Styracocrinus peracutus (Peck) 10. Detail of facet, E-15510; 11,12, lateral views, E-45670, E-45669.

13—Discocrinus wrighti Peck, n. sp. Lateral view of holotype, E-15512.

14,15—Unidentified primaxils, interior and exterior views, E-45900-1.

16,17—Orthogonocrinus excavatus Peck, n. sp. 16, oral view of holotype, E-15635; 17, lateral view of paratype, E-15636.

18–21—Roveacrinus rugosus Douglas. 18, lateral view, E-25711; 19, lateral view of holotype. E-45698; 20,21, lateral views showing variation in ornamentation, E-25710, E-24516.

by a drawing made at the British Museum in 1951 by Mrs. Vaona Peck.

R. communis is by far the most abundant representative of the Roveacrinidae in the European Cretaceous. The species is fairly limited in time (upper Cenomanian through Santonian) but is abundant and widely distributed through England, France, and Germany. The British Museum collections contain more than 125 individuals that are referred to this species.

With such an abundant representation of individuals there are many variations introduced. The lectotype and the other specimens in the A. W. Rowe collection are elongate conical calyces, somewhat angular in section and with medium size radial facet supports that, on most individuals, end as sharp points just below the aboral end of the calyx. Some of the specimens show a bifurcation of the radial facet support just below the arm facet and such a specimen was chosen as lectotype because this feature appears in an illustration given by Douglas. These specimens from the Rowe collection closely resemble the forms described from Germany by Sieverts as *Roveacrinus westphalicus* and definitely represent the same species, as indicated in the above synonomy. A few of the specimens in the Rowe collection have part of the radial facet supports thickened near the aboral end of the calyx and extending as strong diverging spines below the calyx. A peculiar thing about this development is that only from one to three of the radial facet supports on any one specimen are so extended. The others show no sign of the thickening and end as points slightly below the aboral pole. Evidently Douglas noted these aborally projecting spines and assumed that all specimens not possessing five of them were broken, so his illustration shows them restored.

On another group of specimens, not so abundantly represented, all five radial facet supports do extend beyond the aboral end of the calyx but they are grown together as a single projection. On many of these specimens the radial facet support is constricted just below the arm facet, thence expends proximally and again tapers toward the aboral point. In general, specimens in which this variation can be recognized are more coarsely ornamented than the others. These constitute the type of calyx described by Jaekel as *Drepanocrinus sessilis*.

When this study was started it was thought that three or more species could be differentiated. At that time the forms with the aborally extended and divergent radial facets supports were referred to *R. communis*: the specimens with the aborally extended and coalesced radial facet supports were representatives of *R. sessilis* (Jaekel); and the crinoids of this general form but without extended radial facet supports belonged to the species *R. westphalicus* Sieverts. Future collecting and study may prove that these three named species are valid but, in single collections, all three variations are found with many intervening gradations. It is believed that all were part of an interbreeding population and that they represent only individual variations. The German forms referred to *R. sessilis* do have slightly larger and more rounded facets than the English specimens and, therefore, may deserve specific differentiation.

ROVEACRINUS RUGOSUS Douglas
Plate 106, figures 18–21

Roveacrinus communis var. *rugosa* Douglas, 1908 Geol. Mag., Decade 5, vol. 5, p. 359, pl. 17, fig. 5.

Short conical calyces averaging about 1.3 mm. in length and 1.5 mm. in width. Radial facet supports broad, flat, rugose, grading proximally into the surface of the bulbous centrodorsal. Ornamentation consists of comparatively large, somewhat sinuous ridges that parallel the interradial sutures. Radial plates raised along interradial sutures to produce a fairly prominent interradial ridge which ends at the distal surface of the centrodorsal or continues across the centrodorsal.

Radial facets large, occupying most of the distal surface of the radial, semicircular to subangular in shape. Central canal large, located on the inner border of the facet and extending from the inner border to the transverse ridge. Interarticular ligament fossae small and located along the sides of the central canal. Dorsal ligament fossae large, occupying approximately one-half of the radial facet, ligament pit deep.

Types.—Holotype E-45698, figured speci-

mens E-24516, E-25710–11, British Museum (Natural History) Geological Department.

Occurrence.—Coniacian (*Micraster cortestudinarium* zone), Seaford Head, Sussex; Slines Oak Pit, Worms Heath, Upper Warlingham, Surrey Santonian, Pebblecombe corner and of Headley Heath, Surrey, England.

Discussion.—In the A. W. Rowe collection of microcrinoids at the British Museum, and presumably available to Douglas when he wrote the paper in 1908, are four small conical calyces to which he may have been referring when he described *R. communis* var. *rugosa*. Three of these four calyces are here interpreted as young of *R. communis*. The fourth has flattened radial facet supports that are somewhat rugose and grade into the bulbous surface of the centrodorsal. This fourth specimen has been selected as the holotype.

R. rugosus is closely related to *R. communis* and it is difficult to determine whether some specimens should be considered *R. rugosus* or the young of *R. communis*. A valid criterion in most cases is the development of the radial facet supports. If they grade into the surface of the centrodorsal and lose their identity before reaching the aboral end of the calyx the specimen is referred to *R. rugosus*, regardless of whether the support is flattened or rugose. If the radial facet supports continue over the centrodorsal to the aboral end of the calyx the specimen is generally regarded as a young representative of *R. communis*. Other characters, such as the thickness of the radial plates and the development of the radial facets are useful in determining whether the specimens are mature individuals.

Excellent rugose representatives of *R. rugosus* occur in abundance with typical elongate representatives of *R. communis* and it is believed that two distinct species are represented.

Douglas (1908) pointed out that most representatives of *R. rugosus* had an opening at the aboral pole which he interpreted as a stem facet. The openings exist in many specimens but they show no evidence of a stem attachment. The centrodorsal wall is very thin and delicate aborally and it is believed that the openings represent breakage, resorption, or failure to calcify.

ROVEACRINUS BAIRSTOWI Peck, n. sp.
Plate 106, figures 1–6

?Drepanocrinus sessilis SIEVERTS, 1932, Preuss. geol. Landesanstalt, Jahrb., vol. 53, fig. 6a.

Calyces conical, averaging about 1 mm. in width and height, coarsely porous, and possessing small weakly developed arm facets. Radical facet supports extending proximally as ridges that grade into the surface of the centrodorsal or maintain their identity across the centrodorsal to the aboral end of the calyces, the supports developed into strong elongated spines radiating from the base of the arm facets. Centrodorsal globular, smooth or ornamented by short, laterally directed spines located in the interradial position. On the holotype, a comparatively smooth specimen, the centrodorsal is divided into five unequal parts that occupy the positions of basal plates. All other specimens studied are coarsely porous and strongly ornamented and the basal (?) sutures could not be determined.

Radial facets small, occupying about one-third of the upper surface of the radial. Dorsal ligament fossae small, rounded, most of the facet below the transverse ridge occupied by the ligament pit. Transverse ridge comparatively prominent, extending laterally beyond the sides of the facet as small, laterally directed knobs. Central canal smaller than the ligament pit. Small flattened areas, the interarticular ligament fossae, are located along the sides and immediately above the central canal. Brachials small, coarsely porous, each decorated by a short, laterally directed spine.

Types.—Holotype E-25701; figured paratypes E-25702, E-24514, E-15633, unfigured paratypes E-15500–02, E-15634, E-24515, E-25703–4, E-45805–8; British Museum (Natural History) Geological Department.

Occurrence.—Coniacian (*Micraster cortestudinarium Zone*) Slines Oak Pit, Worms Heath, Waldingham Surrey; Santonian (*Micraster coranguium zone*) Northfleet, Kent; Senonian, Pebblecome corner end of Headley Heath, Surrey.

Discussion.—As defined above the species *R. bairstowi* encompasses a group of

crinoids characterized by strong radial spines, small and weakly developed arm facets, and coarsely porous calyces. Aside from these characters there is considerable variation within the species. The holotype possesses very little ornamentation other than the radial spines and the ridges marking the calyx sutures. One paratype (Pl. 106, fig. 2) has well developed interradial spines on the centrodorsal. Another paratype (pl. 106, fig. 4) has a flat base and strong radial ridges extending to the aboral end. In spite of these variations it is believed that the crinoids referred to *R. bairstowi* are closely related and should be contained within one species.

A remarkably well preserved specimen has been chosen as the holotype of *R. bairstowi*. The sutures on the centrodorsal are clearly seen and divide that portion of the calyx into five plates. Two of the plates are larger than the others and one of the five is very small. There is a peculiar pit at the proximal end of each radial suture. The areas between the radial facet supports and the interradial sutures are depressed and small oblique ridges divide the depressions into pits. The arm facets are ended proximally almost on top of the radial spines and are separated from the spines by a slight depression that would allow some movement of the first brachial. The radial spines appear to be composed of two parts, one part extending out from the radial facet and the lower part extending out from the radial facet support. This longitudinal dividing line is clearly visible on all five of the spines.

When the holotype was first studied it was thought that the sutures dividing the centrodorsal gave clear evidence as to the formation of the structure from the basal plates. Another specimen in this collection, referred to *Roveacrinus communis* Douglas, has a pentagonal division of the horizontal partition between the proximal cavity and the calyx cavity. This division can also be interpreted as being formed from the basal plates.

Roveacrinus bairstowi closely resembles *Roveacrinus euglypheus* Peck from the Grayson (lower Cenomanian) of Texas. On *R. euglypheus* the centrodorsal is ornamented by ridges that occupy the same position as the "basal sutures" on the holotype of *R. bairstowi*. Peck (1943) could find no evidence that these ridges actually represented sutures.

The species is named in honor of Dr. Leslie Bairstow, Keeper of the echinoderm collections at the British Museum (Natural History) Geological Department.

Genus Discocrinus Peck, 1943

Roveacrininae with large arm facets located on the outer sides of the radials and almost parallel to the dorsoventral axis.

Type species.—*D. catastomus* Peck from the Comanchean Cretaceous (Albian) of Texas.

Discussion.—The genus *Discocrinus* was established with one species to include a collection of about 70 calyces from the Duck Creek and Fort Worth formations. The original generic description included the location of the large muscular fossae on the distal ends of the radials, in a different plane from the rest of the arm facet. Study of the British specimens indicates that this character is only of specific importance.

Brachials of this genus have not been identified.

Discocrinus wrighti Peck, n. sp.
Plate 106, figure 13

Medium size calyces with observed dimensions of less than 1 mm. in height and less than 2 mm. in width. Proximal cavity open because of breakage or resorption. Interradial ridges prominent, imparting a distinctly pentagonal outline from an end view. Calyces covered with a reticulate network of ridges.

Radial facets elongate oval with sides parallel above the transverse ridge, rounded proximally, the part containing the dorsal ligament fossae and ligament pit vertical in position, the part distal to the transverse ridge in a slightly different plane but approaching vertical. Interarticular ligament fossae elongate dorsoventrally, ending distally against a fairly prominent ridge. Muscular fossae comparatively large for the family, situated on the upper outside corners of the arm facet and in the same plane as the interarticular ligament fossae. Dorsal ligament fossae and ligament pit well developed. Calyx cavity wide and shallow.

Types.—Holotype E-15512, paratype E-

15517, British Museum (Natural Hisotry) Geological Department.

Occurrence.—Cenomanian chalk marl, 10 feet above the base, north of Cambridge, England.

Discussion.—Only two representatives of this species are present in the British Museum collections. *D. wrighti* is larger than *D. catastomus*, and has more prominent interradial ridges. The termination of the interarticular ligament fossae against a horizontal ridge, and the location of the muscular fossae in the same plane as the interarticular ligament fossae are characters of *D. wrighti*.

The name is in honor of Mr. James Wright of Edinburgh who has done excellent work on the Carboniferous crinoids.

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OSTRACODES FROM THE TYPE SECTION OF THE FERN GLEN FORMATION[1]

RICHARD H. BENSON
University of Kansas, Lawrence

ABSTRACT—Ostracodes have not been previously described from the Osage group (Mississippian) of the Upper Mississippi Valley. The type section of the Fern Glen formation of St. Louis County, Missouri, has yielded ten species of Ostracoda, all of which are described and illustrated. They represent the genera *Bairdia*, *Graphiadactyllis*, *Kirkbya*, *Roundyella*, and *Paraparchites*. Six species are new, *B. merivia*, *G. moridgei*, *G. ferngleneusis*, *K. ferngleneusis*, *K. keiferi* and *R. mopacifa;* one, *G. granopunctatus* (Ulrich and Bassler), has been previously described; three, *G.* aff. *G. lineata* (Ulrich and Bassler), *G.* cf. *G. cornutus* (Ulrich & Bassler) and *P.* cf. *P. nicklesi* (Ulrich), show close relationships to described forms. The type section is described in detail, and its stratigraphic relationships are discussed.

INTRODUCTION

IN GENERAL, the stratigraphic value of any group of fossils increases in proportion to the number of faunules described from established reference localities. So far, no ostracodes have been described from the Osage group in the Upper Mississippi Valley, and only three assemblages have been described from Osage and Kinderhook rocks in the United States.

The field work which led to the discovery of this fauna was done under the direction of Dr. C. W. Collinson of the Illinois State Geological Survey. Dr. Collinson also assisted in the laboratory work and critically read the manuscript. Professor H. W. Scott of the University of Illinois supervised the study of the ostracodes and Dr. I. G. Sohn of the U. S. Geological Survey critically examined the manuscript.

STRATIGRAPHY

The Fern Glen formation was originally described by Stuart Weller (1906, p. 438) and, although the formation and its fauna have been the subject of numerous studies, the ostracodes have not been described. All the specimens in this report were secured from Weller's type locality at Fern Glen Station on the Missouri Pacific Railroad about twenty miles southwest of St. Louis.

The Fern Glen formation is one of the lowermost units of the Osage group in southwest Illinois and northeast Missouri. In the type area, the lower part of the formation consists of red, calcareous, somewhat cherty, fossiliferous shales which grade upward into greenish calcareous shales and cherty limestones. Scattered crinoid fragments produce a granular appearance. The red color is largely replaced by green to the northeast, but becomes more prominent to the southeast in Monroe County, Illinois, and Ste. Genevieve County, Missouri. In outcrops near Chautauqua, Jersey County, Illinois, the formation is predominantly green, and is red only in irregular patches.

The lower boundary of the Fern Glen formation is generally well-defined by a marked unconformity. Underlying it are beds ranging stratigraphically from the Maquoketa shale (Ordovician) at Valmeyer, Monroe County, Illinois, to the Sedalia (Mississippian) at Chautauqua, Jersey County, Illinois (Buschbach, 1952, pp. 108–115). Criteria for determining the upper limits of the Fern Glen are less certain; the formation grades into the superjacent Burlington formation. At the type locality, Weller and others placed the upper boundary at the upper limit of the green argillaceous zone, which is the boundary used in this report.

The Fern Glen formation crops out in the general vicinity of St. Louis. It extends around the northeast flank of the Ozark dome from Grafton, Jersey County, Illinois, in the north, at least 80 miles southeast to Chester, Randolph County, Illinois, where

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it has been found in subsurface. It may extend farther south in subsurface, and is possibly equivalent to the St. Joe limestone of northern Arkansas. The exact boundary of the Fern Glen in the Eastern Interior Basin is poorly defined, but the formation does not extend far into Illinois before it loses its distinctive characteristics. It is 30 to 40 feet thick in the Mississippi River Valley outcrops, and it thickens laterally into the basin.

The stratigraphic section at Fern Glen Station, SE ¼, SE ¼, sec. 14, T. 44 N., R. 4 E., St. Louis Co., Mo. (Text-fig. 1) follows:

Bed no.	Description	Thickness (inches)
	BURLINGTON FORMATION	
13	Limestone, light buff, silty; shale, light buff, crinoidal, fossiliferous; chert, greenish-gray to dove-gray, chalcedonic, fossiliferous.	56
	FERN GLEN FORMATION	
12	Shale, light buff, calcareous, silty, slightly fossiliferous, dark grains of fine silt throughout; 20% of bed consists of limestone nodules.	15
11	Limestone, red, very cherty, very fossiliferous, continuous and massive, fossils replaced with light gray chert.	4–5
10	Shale, red, highly calcareous, with thin-bedded limestone throughout.	35
9	Limestone, reddish and light buff, slightly silty, very fossiliferous and crinoidal, ostracodes, thin bedded and flaggy, layer of chert nodules near base.	17
8	Shale, red with few light buff spots, highly calcareous, crinoidal, slightly silty, fossiliferous in upper part, ostracodes.	60
7	Limestone, red, silty, shaly; where weathered, slightly less than 50% projects as limestone stringers.	40
6	Shale, green with red splotches, calcareous, silty, fossiliferous, ostracodes.	2
5	Limestone, red with disseminated buff splotches, silty and sandy, crinoidal, alternating massive and shaly beds averaging two inches in thickness.	30
4	Shale, red, mottled light buff, calcareous, slightly silty.	6
3	Limestone, light buff, mottled red, silty, crinoidal, fossiliferous; forms ledge.	5–6
2	Shale, red, calcareous, silty, crinoidal, fossiliferous.	4
1	Limestone, red, silty, chert nodules 65 inches above base; chert is mottled red, fossiliferous, small brachiopods, cup corals, and crinoids. Exposed	120

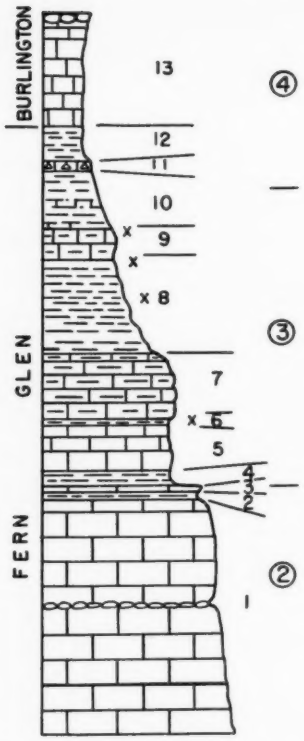
FERN GLEN OSTRACODA

The collection under consideration contains ten species, five genera, and four families. Six of the species are new, one has been previously described from other formations, and three have affinities with described species. All the specimens were collected near Fern Glen Station. The preservation is generally poor; most of the specimens were covered with secondary calcite and were cleaned with some difficulty. Weathering has obscured the ornamentation on many of the specimens. Approximately 150 specimens were obtained; about three-fourths were identifiable, of which 26 have been illustrated.

The faunule contains members of the families Kirkbyidae, Quasillitidae, Bairdiidae, and Leperditellidae. According to Sohn (1954, p. 19), classification of the genus *Roundyella* is uncertain and it therefore may represent an additional family. The genera represented include *Kirkbya*, *Graphiadactyllis*, *Bairdia*, *Roundyella*, and *Paraparchites*. Specimens of *Graphiadactyllis* are more abundant than any other genus, but most of them are very poorly preserved. The many well-preserved specimens of the large *Kirkbya fernglenensis*, n. sp., represent four instar stages. Very few specimens of *Kirkbya keiferi*, n. sp., were found. The genus with the fewest representatives is *Paraparchites;* only four specimens were found and all these are worn. *Graphiadactyllis* exhibits the greatest variation; the five species found differ greatly in size and surface ornamentation. The genus *Kirkbya* includes two species. The remaining genera, *Roundyella*, *Paraparchites*, and *Bairdia*, are represented by only one species each. The length of specimens ranges from 1.96 mm. in *K. fernglenensis* to 0.50 mm. in the smallest instars of *R. mopacifa*.

STRATIGRAPHIC SIGNIFICANCE

Because of the paucity of described ostracodes from the Lower and Middle Missis-



TEXT-FIG. *1*—Diagrammatic profile of the Fern Glen outcrop near Fern Glen Station, Mo. Circled by Weller (1906). X denotes zones yielding ostracodes. Plain numbers refer to the beds described.

sippian, the full stratigraphic significance of this particular faunule will not be clear until more related material has been described from other Mississippian formations. Three ostracode assemblages have been described from the Osage and Kinderhook groups: from the Bushberg sandstone of Missouri (Morey, 1935), from the Chouteau formation of Missouri (Morey, 1936), and the Ridgetop formation of Tennessee (Bassler, 1932, pl. 27). The Ridgetop is thought to be Fern Glen in age (Wilson and Spain, 1936). However, only two species are common to the Ridgetop and Fern Glen faunas (*Graphiadactyllis granopunctatus* and *G.* cf. *G. cornutus*). The next younger faunules described are from the Salem formation in Indiana (Geis, 1932) and Missouri (Brayer, 1952). Ulrich (1890, 1891) described a few forms from the "St. Louis Group" at Columbia, Monroe County, Ill., but only one species, *Paraparchites nicklesi* (Ulrich), is comparable to forms found in the Fern Glen fauna.

The ostracodes found in the Fern Glen formation represent what might be called a typical early Mississippian assemblage, and most Devonian elements are absent. The predominant genus *Graphiadactyllis*, whose range is from the Devonian to the Pennsylvanian, seems to be at a peak in number and diversity of form. The genera *Bairdia*, *Paraparchites*, and *Kirkbya*, range throughout the Mississippian system, and therefore are not in themselves significant. *Roundyella* has not previously been identified with certainty below the Salem (Brayer, 1952), and its presence in the Fern Glen may represent a first appearance. According to Sohn (1954, p. 19), the Devonian forms that have been assigned to *Roundyella* by Pokorny (1950, pp. 544–546, 607–608) are probably not congeneric with the type. There is also some doubt as to the correct affinities of the form from the Middle Devonian (Hamilton) of Ontario identified as *Amphissites simplicissimus* by Coryell and Malkin (1934, p. 4). This generic reference was rejected by Cooper (1946, p. 109) and Brayer (1952, p. 172). Sohn (1954, p. 19) suggests that the species must be studied further before its classification is certain.

Most of the species in the Fern Glen faunule are not known from any other formation. *Graphiadactyllis granopunctatus* (Ulrich and Bassler) is the only previously described species. It occurs with *G.* aff. *G. lineata* (Ulrich and Bassler) and *G.* cf. *G. cornutus* (Ulrich and Bassler) in both the Chouteau formation and the Ridgetop shale. *Paraparchites* cf. *P. nicklesi* (Ulrich) occurs below the Fern Glen in the Bushberg formation and its range extends upward into the Chester series.

ECOLOGY AND FAUNAL ASSOCIATIONS

The ostracodes of the Fern Glen at the type locality seem to be concentrated mainly in the red shale, particularly in the upper part of bed no. 8 (Text-fig. 1) where the formation begins to grade into the overlying cherty light buff crinoidal limestone. No ostracodes were found in any of the samples of the green calcareous shale.

Small instars were absent in the samples

collected, probably because of the fragility and solubility of the small delicate carapaces, which were not able to withstand the conditions of the environment of deposition. Broken, worn fragments of the larger instars are common. Most specimens show either solution of the surface or coating with secondary calcite.

The biostrome, of which the ostracodes are but a small part, consists predominantly of crinoidal debris. Second in abundance are small solitary corals and large brachiopods. Many unidentified brachiopods of microscopic size are also present. Bryozoans and gastropods are common but not abundant. The fauna found associated with the ostracodes is as follows:

Anthozoa
- *Cyathaxonia* sp.
- *Amplexus rugosus* Weller
- *Palaeacis depressus* (Meek & Worthen)

Conodonta
- *Hindeodella* spp.
- *Polygnathus* spp.

Bryozoa
- *Evactinopora sexradiata* Meek & Worthen

Brachiopoda
- *Athyris lamellosa* (L'Eveillé)
- *Cleiothyridina prouti* (Swallow)
- *Spirifer vernonensis* Swallow
- *Brachythyris ferngleneusis* Weller
- *Chonetes logani* Norwood & Pratten
- *Dictyoclostus ferngleneusis* (Weller)
- *Rhipidomella jerseyensis* Weller?
- *Spiriferina subtexta* White

Gastropoda
- *Platyceras paralius* White & Whitfield
- *Ptychospira sexplicata* (White & Whitfield)

SYSTEMATIC PALEONTOLOGY

Family BAIRDIIDAE Sars 1887
Genus BAIRDIA McCoy, 1844
BAIRDIA MERIVIA Benson, n. sp.
Plate 107, figures 7, 12

Carapace moderate in size, subrhomboidal, almond-shaped in lateral view; dorsum semi-ovate, approaching flatness in central third; venter almost straight with very slight concavity just posterior of median line, posterior and anterior thirds gently convex upward. Greatest length slightly ventral of midline, greatest height in anterior half, greatest thickness in dorsal view immediately postmedial. Anterodorsum and posterodorsum truncated with very slight convexity, anterodorsal slope shorter than posterodorsal, anterodorsum and anteroventer meet to form an angle more obtuse than posterior dorsoventral angle. Greatest convexity in ventral half of carapace. Valves subequal, overlap weak and obscure. Interior of carapace oblong, equally concave both anterior and posterior. Exterior surface finely granuloreticulate. Length of holotype 1.16 mm.; height, 0.56 mm.; width, 0.55 mm.

Remarks.—*B. merivia* can be distinguished from other members of the genus by its broadly convex dorsum, nearly straight venter, and straight truncated posterodorsum. Also, the area of occlusion of the hingement is much wider than is generally found in other species of *Bairdia*. It differs from the type species *B. curta* McCoy from the Carboniferous of Ireland in that the anterior and posterior extremities are acute rather than acuminate or cuspidate. *B. merivia* is named for the Meramec River in whose valley the type section of the Fern Glen formation is located. Only seven specimens were collected and all were single valves. The species is based on so few individuals that its validity may be uncertain, but it is seemingly unique.

Repository.—Illinois State Geological Survey Paleontology Coll.: holotype, B-651411.

Family QUASILLITIDAE Coryell and Malkin 1936
[Graphiodactylidae KELLETT, 1936]
Genus GRAPHIODACTYLUS Roth 1929

Graphiadactyllis ROTH, 1929, Wagner Free Inst. Sci. Publ. no. 1, p. 10.
Graphiodactylus ROTH, 1929, Jour. Paleontology, vol. 3, pp. 292, 293.
Bassleria HARLTON, 1929, Amer. Jour. Sci., ser. 5, vol. 18, p. 255.
Paracythere ULRICH & BASSLER, 1932, Tenn. Div. Geol., Bull. 38, pl. 27, figs. 4, 13.
Barychilina ULRICH [part], ULRICH & BASSLER, Tenn. Div. Geol., Bull. 38, pl. 27, fig. 2, 3.
Allostracites PŘIBYL, 1953, Czechoslovakia Stàtni Geol. Ûstav. Sbornik, sv. 20, p. 109.
Graphiodactylus SWAIN, 1953, Jour. Paleontology, vol. 27, p. 270.

GRAPHIADACTYLLIS FERNGLENENSIS Benson, n. sp.
Plate 108, figures 5, 11, 13, 15, 16, 17

Carapace large, subrhomboidal in lateral view; dorsum slightly undulatory, almost straight; venter swings posteriorly, uniformly convex. Greatest extension of anterior below midline; of posterior above the midline; anterodorsal slope long, postero-

dorsal slope absent, uniformly convex. Greatest height in anterior third, greatest thickness postmedial in dorsal view, anterior cardinal angle obtuse. Anterior region broadly convex below the midline, posterior well rounded. Anterior cardinal angle obtuse in adult, more acute in younger instars; posterior cardinal angle less pronounced and more obtuse in immature instars than in adults. Hingement straight, occupying two-thirds shell length. Valves thick and robust, wide area of occlusion of interior hinge and free margin. Surface uniformly punctate to slightly reticulate, depending on state of preservation. Shell slightly flattened posteriorly, parallel with the margin, emphasizing general inflation toward the anterior. Interior surface smooth with slightly raised smooth area of adductor muscle attachment near midpoint. Length of holotype, 1.60 mm.; height, 0.85 mm.; width, 0.75 mm.

Remarks.—Details of the hingement are obscured by weathering, but a broad tooth-and-socket arrangement can be seen; the latter is contained in the left valve. *G. fernglenensis* can be distinguished from all other species of *Graphiadactyllis* by its large size, posterior flattening parallel to the margin, punctate surface, and robust construction. The species is very similar in size and general outline to the type species *G. arkansana* (Girty) from the Fayetteville shale of Arkansas as figured by Roundy (1926), but the surface ornamentation is not the same. *G. arkansana* (Girty) appears to have an exterior surface pattern very like a "fingerprint" design in the unweathered specimens; such a configuration is not present in *G. fernglenensis.* However, it seems possible that some of the specimens from the Barnett shale of Texas, assigned to *G. arkansana* (Girty) by Roundy and described as smooth, actually may be conspecific with *G. fernglenensis.* About 15 specimens were found.

Repository.—Illinois State Geological Survey Paleontology Coll.: holotype, B-65327; paratypes, B-65328, B-65329.

GRAPHIADACTYLLIS GRANOPUNCTATUS (Ulrich & Bassler), 1932
Plate 108, figures 7, 9, 10, 12

Paracythere granopunctata ULRICH & BASSLER, 1932, Tenn. Div. Geol., Bull. 38, pl. 27, fig. 4; BASSLER, 1939, Jour. Wash. Acad. Sci., vol. 25, p. 409.

Graphiodactylus granopunctatus MOREY, 1936, Jour. Paleontology, vol. 10, no. 2, p. 117, pl. 17, figs. 20, 21, 24, 27.

Allostracites granopunctata PŘIBYL, 1953, Czechoslovakia Státni Geol. Ûstav. Sbornik, sv. 20, p. 109.

Remarks.—The surface ornamentation is severely worn in many individuals (Pl. 108, fig. 7), but these specimens conform to the original description in every other respect. About 10 specimens were found.

Repository.—Illinois State Geological Survey Paleontology Coll.: hypotypes B-65325, B-65326.

Occurrence.—Fairly abundant in the Chouteau of Missouri, present in the Ridgetop shale of Tennessee and the Fern Glen of Missouri.

GRAPHIADACTYLLIS aff. G. LINEATUS (Ulrich & Bassler), 1932
Plate 108, figures 3, 4, 6

Barychilina lineata ULRICH [part], Tenn. Div. Geol., Bull. 38, pl. 27, figs. 2, 3; BASSLER, 1939, Jour. Wash. Acad. Sci., vol. 25, p. 409.

?Graphiodactylus sp. aff. *G. lineatus* SWAIN [part], 1953, Jour. Paleontology, vol. 27, p. 270, pl. 38, figs. 11b, 11d.

Carapace small, subrhomboidal in lateral view, dorsum very slightly convex; venter straight in center third, convex on ends, venter swings backward. Greatest extension of anterior below the midline, of posterior above the midline; anterodorsal slope much longer than in *G. lineatus*, posterodorsum more rounded. Greatest height at anterior cardinal point, greatest thickness postmedial in dorsal view. Anterior cardinal angle obtuse. Anterior truncated in anterodorsal quadrant, shortly rounded in anteroventral quadrant; posterior moderately well rounded. Hingement straight, occupying half the shell length. Exterior surface ornamentation delicate, consisting of fine riblets arranged longitudinally in midportion, concentrically near margin. Valves thin, moderately convex. Length of hypotype 1.0 mm.; height, 0.60 mm.; width, 0.50 mm.

Remarks.—Very similar to *G. granopunctatus* (Ulrich and Bassler) from the Ridgetop shale of Tennessee in outline, convexity, and robustness; the greatest differences being in the surface ornamentation. Similar to *G. lineatus* (Ulrich and Bassler) from the

Ridgetop shale but has a more definite anterior slope; surface ornamentation similar. About 20 single valves found. Topotypes from the Ridgetop must be studied before this species can be adequately defined.

Repository.—Illinois State Geological Survey Paleontology Coll.; hypotypes, B-65318, B-65319.

GRAPHIADACTYLLIS MORIDGEI Benson, n. sp.
Plate 108, figures 1, 2

Graphiodactylus sp. aff. *G. lineatus* SWAIN [part], 1953, Jour. Paleontology, vol. 27, p. 270, pl. 38, figs. 11a, 11c.

Carapace small, subrhomboidal, very long in proportion to height in lateral view; dorsum straight on left valve, very slightly convex on right valve; venter long and very slightly concave in midthird, height of valve decreases posteriorly. Greatest extension of anterior below midline, of posterior at midline; anterodorsal slope long, posterodorsal slope very short. Greatest height in anterior third, greatest thickness in dorsal view is posterior to midpoint. Cardinal angles very obtuse, posterior angle greater than anterior. Flange is integral part of main carapace, proximal limits not distinct, ends dorsal to midline on anterior end. Flange extends anteriorly and forms small spine on right valve. Hingement straight, occupying one-third of shell length. Valves thin and delicate, almost circular in vertical cross section near midpoint. Exterior surface ornamentation faint and delicate with concentric riblets running longitudinally and converging along the anterior midline for one-fourth the distance of the shell, concentric near free margin. Length of cotype 0.96 mm.; height, 0.5 mm.; width, 0.3 mm.

Remarks.—This species may be distinguished from *Graphiadactyllis lineatus* (Ulrich and Bassler) and *G. cornutus* (Ulrich and Bassler) by its long slim outline and the horizontality of the riblet pattern of the surface ornamentation. Because of thin shell walls and translucency of the shell material, the flange outline is easily visible from the exterior. Some of the specimens described in 1953 by Swain as *Graphiadactyllis* sp. aff. *G. lineatus* (Ulrich and Bassler) possess a well-developed anterior spine and are elongate in outline. Therefore, I am assigning them to *G. moridgei*. This species is also very similar in shape, but not in ornamentation, to *G. axea* Brayer, from the Salem formation of Missouri. This species is named for Mountain Ridge Station, a stop on the Missouri Pacific Railroad near Fern Glen Station, Mo. Fifteen single valves were found.

Repository.—Illinois State Geological Survey Paleontology Coll.: syntypes, B-65320, B-65321.

GRAPHIADACTYLLIS cf. G. CORNUTUS (Ulrich and Bassler), 1932
Plate 107, figures 1, 2, 3, 9

Paracythere cornuta ULRICH & BASSLER, 1932, Tenn. Div. Geol. Bull. 38, pl. 27, fig. 13; BASSLER, 1935, Jour. Wash. Acad. Sci., v. 25, no. 9, p. 409.

Graphiodactylus cornutus MOREY, 1936, Jour. Paleontology, v. 10, no. 2, p. 117, pl. 17, fig. 22.

Carapace subrhomboidal in lateral view; dorsum straight; venter swings posteriorly. Greatest extension of anterior below midline, of posterior slightly above midline, anterodorsal slope long. Greatest height in anterior third, greatest thickness in dorsal view is postmedial. Anterior cardinal angle about 115°, posterior cardinal angle less obtuse. Anterior end subrounded, posterior end subrectangular. Hingement straight, occupying three-fourths of the shell length. Dorsum extends beyond the hingement both posteriorly and anteriorly, more on the left valve than on the right, slight indication of teeth on hinge of right valve and corresponding sockets on left valve. Valves moderately thick, moderately convex. Exterior surface ornamented by delicate, narrow, bifurcating and anastomosing riblets oriented longitudinally in midanterior and concentrically over the remainder of the shell. Maximum flange development in anteroventral quadrant, ending abruptly at midline to form small anterior spine, which tapers posteriorly to join main shell at midventer; indistinguishable from main carapace in exterior lateral view. Posteroventral flange directed toward posterior, ventral margin subparallel to dorsum, ends abruptly anterior of posterior extremity. Small spine on the left valve of one specimen directed toward posterior on the posterior margin halfway between the cardinal point and the midline. Length of largest

specimen 0.95 mm.; height, 0.58 mm.; width, 0.50 mm.

Remarks.—This species is easily distinguished from other forms in the faunule, for it has the best developed and best preserved "fingerprint" ornamentation. It is further distinguished by the small anterior spine development of the flange on both valves, the posteroventral flare in the flange of the right valve, and the well-developed bifurcating and anastamosing fingerprint-like riblets. It differs from *G. moridgei* in that the carapace is not as elongate and has a predominance of concentric rather than longitudinal riblets. *G.* cf. *G. cornutus* has a different arrangement of spines and riblets from *G. subquadratus* Morey from the Sylamore sandstone of Missouri. *G.* cf. *G. cornutus* is important even though it is not abundant because it is represented in the Ridgetop shale (Bassler, 1932) and Chouteau formation (Morey, 1936). About 10 specimens were considered in this description.

Repository.—Illinois State Geological Survey Paleontology Coll.: hypotypes, B-65307 to B-65310.

Family KIRKBYIDAE Ulrich and Bassler, 1916

Genus KIRKBYA Jones, 1859

KIRKBYA FERNGLENENSIS Benson, n.sp.

Plate 107, figures 11, 13, 17, 18

Carapace subrectangular, canoe-shaped, noticeably inflated in lateral view; dorsum approaches straight, slightly undulatory due to swelling; venter subsemicircular, slight backward swing. Greatest length above midline; greatest height in posterior third; greatest thickness in dorsal view, postmedial. Anterior and posterior cardinal angles subequal, right angles to slightly acute. Primary swelling in posterior half, secondary swelling in anterior; very shallow poorly defined medial depression. Hingement straight, occupying entire length of shell. Exterior reticulate, with ovate to polygonal depressions, four rows of polygons between the free margin and velum, size and linear orientation of polygons decreases away from velum toward the shoulders. Elongate depressions oriented perpendicular to the hingeline in both anterodorsal and posterodorsal regions adjacent to the velum; moderately striate velum extending from anterior to posterior cardinal points; kirkbyan pit slightly anteroventral to midpoint, very pronounced, surrounded by twelve polygons of the reticulate surface ornamentation. Length of holotype, 1.78 mm.; height, 0.93 mm.; width, 0.9 mm. Length of "Adult-1" instar, 1.60 mm.; height, 0.85 mm. Length of "Adult-2" instar, 1.35 mm.; height, 0.70 mm. Length of "Adult-3" instar, 1.12 mm.; height, 0.61 mm.

Remarks.—This species is best distinguished from the type species *K. permiana* (Jones) and other members of the genus by its large size, distinct shoulders, wide velum, and large kirkbyan pit. The distance from

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EXPLANATION OF PLATE 107

All specimens are from the type locality of the Fern Glen formation, and are illustrated approximately ×34.

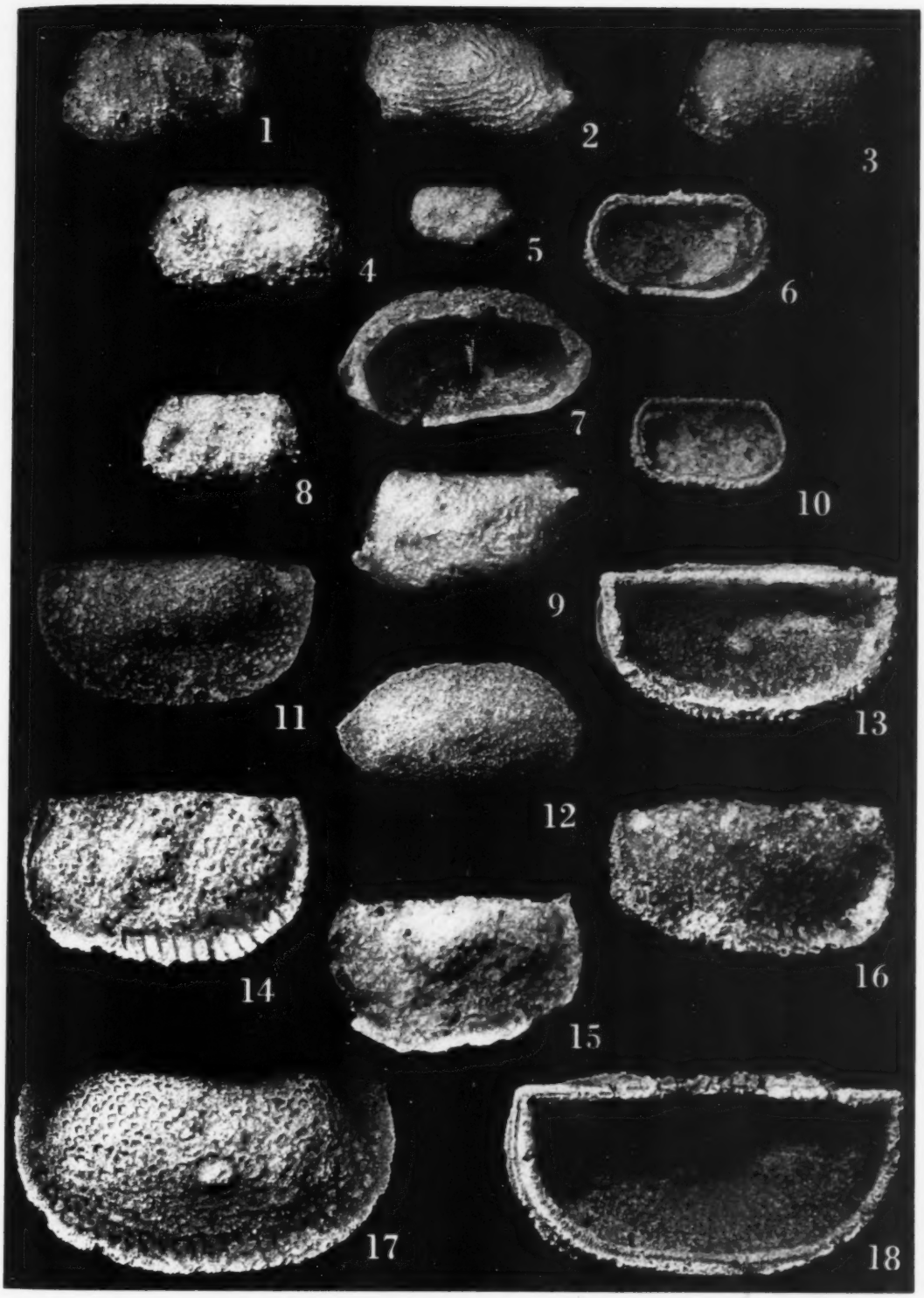
FIGS. *1–3, 9—Graphiadactyllis* cf. *G. cornutus* (Ulrich and Bassler). 1, left valve of a late instar; 2, right valve of a hypotype showing "fingerprint" riblets and anterior spine, the posterior is chipped; 3, left valve of a late instar; 9, left valve of a hypotype with riblets and spines.

4–6,8,10—Roundyella mopacifa Benson, n. sp. 4, right valve of the holotype showing anterior and posterior nodes; 5, right valve of an "adult-3" instar showing a slight development of the nodes; 6, interior of the right valve of a paratype; 8, right valve of an "adult-1" instar showing the prominent anterior and posterior nodes; 10, interior of an "adult-1" instar showing the hinge.

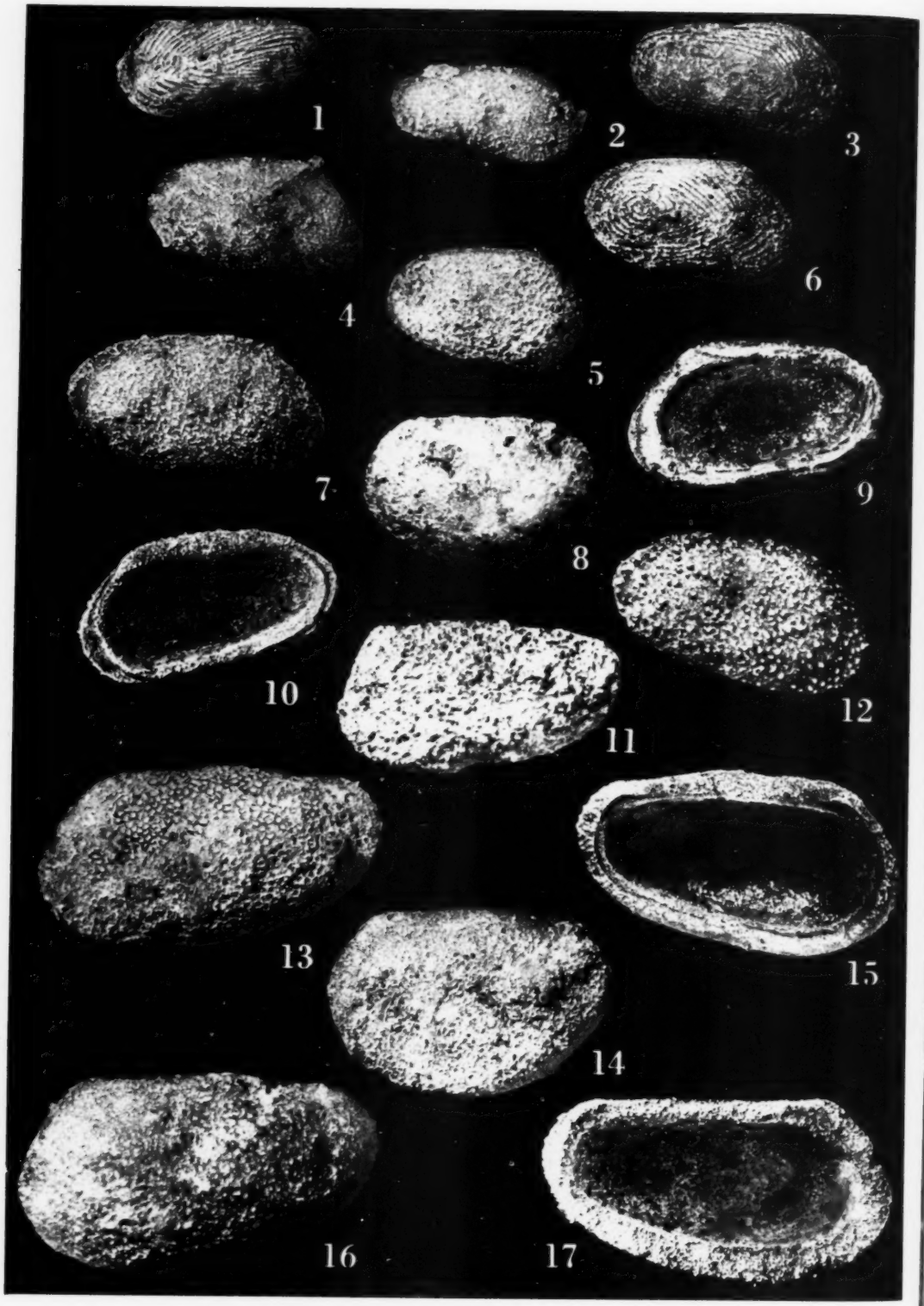
7,12—Bairdia merivia Benson, n. sp. 7, interior of the right valve of the holotype.

11,13,17,18—Kirkbya fernglenensis Benson, n. sp. 11, left valve of an "adult-2" instar showing the adductor muscle scar; 17, right valve of the holotype showing the reticulate surface, striate velum and pronounced pit with a calcite plug; 18, interior of the right valve of the holotype showing the adductor muscle scar and part of the hingement.

14–16—Kirkbya keiferi Benson n. sp. 14, right valve of a paratype showing the striate velum and subdued central swelling; 15, left valve of the holotype showing the pronounced development of the central swelling and a posterior cardinal spine, the anterior part of the velum is broken; 16, right valve of a slightly compressed large individual with a chipped dorsum.



Benson, Mississippian ostracodes from Missouri



Benson, Mississippian ostracodes from Missouri

the kirkbyan pit to the anterior margin is equal to the greatest height of the carapace. The kirkbyan pits in the larger specimens were filled with calcite to form a boss rather than a pit. All specimens were single valves. About twenty specimens were considered in the description of this species.

Repository.—Illinois State Geological Survey Paleontology Coll.: holotype, B-65312; paratypes, B-65313, B-65314.

KIRKBYA KEIFERI Benson, n. sp.
Plate 107, figures 14, 16

Carapace subrectangular in lateral view; dorsum straight; venter very convex. Greatest length above midline; maximum height in anterior half; maximum thickness in dorsal view slightly anterodorsal to midpoint. Anterior and posterior cardinal angles subequal, very slightly obtuse. Swelling generally slight and uniform except for a large ill-defined swelling slightly anterodorsal to midpoint. Hingement straight, extending over the total length of the shell. Valve delicate, irregularly convex. Exterior surface reticulate; polygonal interstices of the reticulate surface very elongate at junction of velum and main carapace causing corrugation of velum perpendicular to edge; three rows of polygonal interstices between velum and free margin; wide velum continuous, narrowing dorsally; small kirkbyan pit slightly anteroventral to midpoint below large central swelling. Small spine on posterior cardinal point of left valve projecting posterodorsally. Five specimens were found. Length of holotype, 1.38 mm.; height, 0.82 mm.; width, 0.40 mm.

Remarks.—*K. keiferi* is readily identified by the unusual swelling in the region of the midpoint, the wide corrugated velum, and the small spine on the posterior cardinal point of the left valve. The general form of the velum is very similar to those of the widely velate members of *Kirkbya*, such as *Kirkbya* cf. *K. reflexa* Girty illustrated by Cooper (1946, pl. 17, figs. 2–4), or *K. fernglenensis* of this paper. *K. keiferi* is named for Keifer Creek, which discharges into the Meramec River near the type section of the Fern Glen formation.

Repository.—Illinois State Geological Survey Paleontology Coll.: holotype, B-65315; paratypes, B-65316, B-65317.

Family Uncertain
Genus ROUNDYELLA Bradfield, 1935

Roundyella BRADFIELD, 1935, Bull. Amer. Paleontology, vol. 22, no. 73, p. 66.
Scabernia BRADFIELD, 1935, Ibid., p. 67.
Roundyella COOPER, 1946, Ill. Geol. Survey Bull., no. 70, p. 108.

ROUNDYELLA MOPACIFA Benson, n. sp.
Plate 107, figures 4, 5, 6, 8, 10

Carapace small, elongate, subrectangular to subelliptical in lateral view; dorsum

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EXPLANATION OF PLATE 108

All specimens are from the type locality of the Fern Glen formation, and are illustrated approximately ×34.

FIGS. *1,2—Graphiadactyllis moridgei* Benson, n. sp. 1, left valve of a syntype showing the riblets and anterior development of the flange; 2, right valve of the other syntype showing longitudinal riblets.

3,4,6—Graphiadactyllis aff. *G. lineata* (Ulrich and Bassler). 3, right valve of specimen with chipped dorsum; 4, right valve of a heavily abraded adult illustrating the common preservation; 6, right valve of a specimens showing concentric and longitudinal "fingerprint" riblets.

7,9,10,12—Graphiadactyllis granopunctatus (Ulrich and Bassler). 7, right valve of specimen illustrating the subdued granulose surface; 9, interior of same specimen; 10, interior of right valve of hypotype showing the hingement and flange development; 12, exterior of the same specimen showing a well-developed granulose surface.

5,11,13,15–17—Graphiadactyllis fernglenensis Benson, n. sp. 5, right valve of an early instar; 11, left valve of a late instar with calcite deposits filling the reticulate surface; 13, left valve of the holotype showing surface reticulation; 15, interior holotype showing the hingement; 16, left valve of a paratype showing the very well-developed cardinal points; 17, interior of same paratype.

8,14—Paraparchites cf. *P. nicklesi* (Ulrich). 8, left valve of a young instar; 14, left valve of an adult or almost adult instar.

straight; venter straight, very slight backward swing. Greatest length along midline, ends of approximately equal height, dorsal anterior cardinal angle slightly more obtuse than posterior. Anterior generally more rounded than posterior. Hingement straight, occupying about five-eighths of the shell length. Carapace very narrow in dorsal view, valves thin, fragile, not very convex. Localized ill-defined swellings slightly below midline on anterior portion and slightly above midline on posterior portion forming two nodes. Entire surface reticulate, small spines around the margin at the radial pore canals may be calcite crystal development during fossilization, kirkbyan pit not well preserved. Length of holotype, 0.89 mm.; height, 0.48 mm.; width, 0.40 mm. Length of paratype "Adult-1", 0.72 mm.; height, 0.41 mm. Length of paratype "Adult-2", 0.60 mm.; height, 0.38 mm. Length of paratype "Adult-3", 0.50 mm.; height, 0.28 mm.

Remarks.—Surface ornamentation is obscured by poor preservation. It is easily differentiated from other members of the genus by the presence of anterior and posterior nodes. Ontogenetic development is reflected in the carapace by an increase in size and distinctness of surface ornamentation. The ill-defined swellings seem to be evident in the smallest instar found, "Adult-3." The pit which is so distinct in *R. simplicissima* (Knight), as illustrated by Cooper (1946, pl. 17, figs. 30, 33, 36), surrounded by a concentric arrangement of the reticulate surface, is obscure if not totally absent. *R. mopacifa* has a vague similarity to *Mauryella mammillata* Ulrich and Bassler, which has six nodes, from the Ridgetop shale of Tennessee and may be related to it. Fifteen complete specimens were considered.

Repository.—Illinois State Geological Survey Paleontology Coll.: holotype, B-65301; paratypes, B-65302 to B-65306.

Family LEPERDITELLIDAE Ulrich & Bassler, 1906

Genus PARAPARCHITES Ulrich & Bassler, 1906

PARAPARCHITES cf. P. NICKLESI (Ulrich), 1891

Plate 108, figures 8, 14

Leperditia nicklesi ULRICH, 1891, Cincinnati Soc. Nat. Hist. Jour., vol. 13, p. 200, pl. 18, figs. 1 a–c.

Paraparchites nicklesi GRABAU & SHIMER, 1910, North Amer. Index Fossils, p. 343, figs. 1657 c–f; GIRTY, 1911, U. S. Geol. Survey. Bull 439, p. 105, pl. 9, figs. 2–5; ——, 1915, Bull. 635, p. 134, pl. 11, fig. 2; HARLTON, 1929, Amer. Jour. Sci., ser. 5, vol. 18, p. 255, pl. 1, fig. 1; CRONEIS, 1930, Arkansas Geol. Survey, Bull. 3, p. 63, pl. 15, fig. 11.; MOREY, 1935, Jour. Paleontology, vol. 9, p. 317, pl. 28, fig. 26; ——, 1935, vol. 9, p. 475, pl. 54, fig. 8; ——, 1936, vol. 10, p. 115, pl. 17, fig. 26; CORYELL & JOHNSON, 1939, idem., vol. 13, p. 214, pl. 25, fig. 1; COOPER, 1941, Illinois Geol. Survey, Rept. Invest. no. 77, p. 62, pl. 14, figs. 5–7; MCLAUGHLIN & SIMONS, 1951, Jour. Paleontology, vol. 25, p. 571, p. 76, figs. 9, 10.

Carapace large, suboval in lateral view with a little backward swing; dorsum straight, well rounded on ends along hinge; venter subcircular. Greatest length dorsal to median, greatest height just anterior of midpoint, greatest thickness postmedial in dorsal view. Cardinal angles obtuse. Anterior end uniformly convex; posterior extremity higher, slightly rounded truncation of the posteroventer. Hingement straight, extending two-thirds of the total shell length; very thin. Valve convexity greatest near venter in anterior view, least along anterior midline as seen in dorsal view. Surface smooth, weathered. Length of adult specimen, 1.41 mm.; height, 0.93 mm.; width, 0.75 mm.

Remarks.—It is very difficult to determine the exact affinities of the species because the specimens are extremely weathered and only four single valves were found. The specimens very closely resemble the weathered specimen illustrated by Morey (1935, pl. 28, fig. 26) from the Bushberg? or Sylamore sandstone of Missouri. *P. nicklesi* is recorded also from the Warsaw, Glen Dean, Batesville, Moorefield, and Fayetteville formations.

Repository.—Illinois State Geological Survey Paleontology Coll.: hypotypes, B-65330, B-65331.

ADDENDUM

After this manuscript was completed, I learned from Professor Dorothy Jung Echols in April, 1954, that a similar study of the Fern Glen ostracodes was being carried on under her supervision at Washington University, St. Louis, by Mr. Jack Gouty. Mrs. Echols kindly criticized this manuscript and she informs me that Mr. Gouty's work

largely agrees with this study but that he has several new species and a new genus in addition to those included here.

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JOURNAL OF PALEONTOLOGY, VOL. 29, NO. 6, PP. 1040–1071, 12 TEXT-FIGS., NOVEMBER 1955

PALEONTOLOGICAL NOTES

MARSUPIPTERUS, AN UNUSUAL EURYPTERID FROM THE DOWNTONIAN OF ENGLAND

KENNETH E. CASTER
University of Cincinnati, Cincinnati, Ohio
AND
ERIK N. KJELLESVIG-WAERING
Tulsa, Oklahoma

The well known Downtonian (Silurian) beds of Herefordshire and Shropshire, England, have furnished many of our best Eurypterida. These have been described in numerous papers by Salter (1852, 1859, 1859a), Woodward (1871, 1866–78), and Kjellesvig-Waering (1951). It is therefore surprising that these beds have not yet revealed their entire content of these fossils and in particular a form such as herein described. The new eurypterid represents a large form of very peculiar characteristics in that the telson has a large pouch-like opening on the ventral side, a feature previously unknown in any of the Eurypterida. The specimen comprises a fairly complete telson preserved in an uncrushed condition in fine-grained sandstone containing many unidentifiable fragments of other eurypterids.

The writers are indebted to Dr. C. J. Stubblefield of the Geological Survey and Museum, London, England, for the loan of this unique specimen, and they wish to express their thanks to him.

Comparison with other Eurypterida on a family level is difficult. The telson, with its pouch-like opening, bears no resemblance to other forms. The styliform spike and the ornamentation suggests the Stylonuridae, and the species is questionably referred to that family until specimens are available which reveal the true taxonomic position.

Family STYLONURIDAE Diener
Genus MARSUPIPTERUS Caster & Kjellesvig-Waering, n. gen.

Telson, styliform; anterior, bulbous with deep ventral pouch; carinated along spike-like posterior. Ornamentation comprises scattered pits. Type species: *Marsupipterus sculpturatus* Caster and Kjellesvig-Waering, n. sp.

MARSUPIPTERUS SCULPTURATUS Caster & Kjellesvig-Waering, n. sp.
Text-fig. 1a-1e

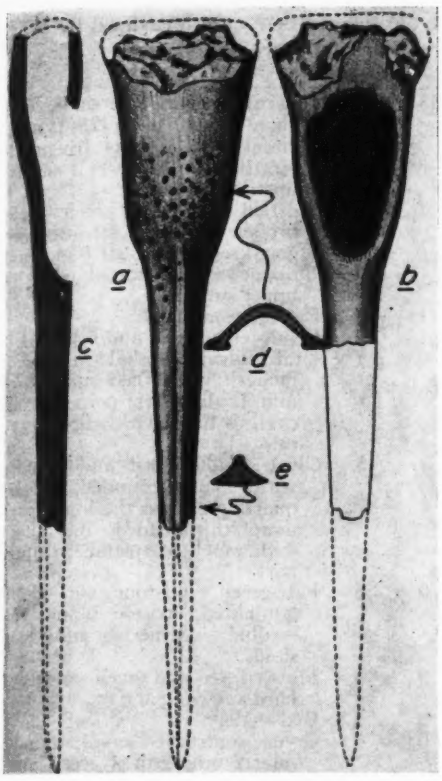
The holotype and only known specimen comprises a large telson preserved in sandstone. It is virtually uncrushed except at the distal end where the blunt carina is partly turned over to the right. The specimen lacks the extreme anterior end and part of the posterior part of the spike. Enough of the telson is preserved to permit an accurate reconstruction.

The telson is bulbous anteriorly, having a deep, rather elliptical pouch developed on the venter. Lateral margins of the telson narrow rather abruptly into a long spike, which is surmounted with a blunt but prominent carina; the underside of the spike is nearly flat, without any carina.

The remarkable pouch-like opening on the ventral side is a feature hitherto unknown in any of the Eurypterida. Its function is unknown, though probably was cloacal. If so, this is apparently an unique extension of the gut into the terminal spine of the merostomes. The walls of the pouch are thick, averaging 4 mm. in thickness. The pouch is 49 mm. in length, 22.5 mm. in width, and 18 mm. in estimated depth.

Length of telson:
  part preserved, 140 mm.
  reconstructed overall length, 210 mm.
Width at anterior end: 44 mm.
Width at mid-section: 15 mm.
Depth at anterior: 23 mm.
Depth at mid-section: 11 mm.

The anterior end of the telson is sculptured with evenly spaced pits. These pits are inconspicuous except under favorable light where they become readily apparent.



TEXT-FIG. 1—Telson of *Marsupipterus sculpturatus* Caster & Kjellesvig-Waering, ×½; a, dorsal side partly restored; b, ventral side partly restored; c, median longitudinal section of telson; d, cross-section through middle part of pouch; e, cross-section through spike.

Horizon and locality.—Upper Silurian Downton Castle sandstone at Forge Bridge, Downton, Shropshire, England.

Depository.—Registered as No. 89467 in the Geological Survey and Museum, London, England. The specimen is from the Smith Collection; it was found in 1858.

Remarks.—Comparison with other Eurypterida is superfluous as the pouch-like structure in *Marsupipterus* is sufficient to distinguish it from all previously described forms. It is difficult, in fact, to assign this genus to any known family, and it is likely that *Marsupipterus* may properly belong in a separate family group. The overall length of this eurypterid, from the anterior rim of the dorsal shield to the end of the telson, probably was of the order of a meter. This is therefore a large form but was nevertheless much smaller than some of the associated Pterygotidae.

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THE PTERYGOTIDAE OF THE SILURIAN VERNON SHALES OF NEW YORK

ERIK N. KJELLESVIG-WAERING
Tulsa, Oklahoma
AND
KENNETH E. CASTER
University of Cincinnati, Cincinnati, Ohio

The Vernon shales of central New York are practically barren of fossils. However, in the middle part of the Vernon, near Oneida, New York, R. Wayland-Smith discovered a thin zone which carries a considerable fauna. R. H. Flower and R. Wayland-Smith (1947, p. 1180) reported that this locality yielded several hundred specimens of a well preserved marine fauna, containing a new siphonophore, a new merostome

genus, eurypterids, brachiopods, cephalopods, pelecypods, and ostracodes. The eurypterids were kindly turned over to the present writers for description, and they are reported herein.

Eurypterids of the Vernon shales were discussed by Ruedemann (1920, p. 205) who reported several forms from the basal part of the formation, taken from the excavations of a barge canal near Pittsford, Monroe County, New York. He identified *Eurypterus pittsfordensis* Sarle, and *Mixopterus multispinosus* Clarke & Ruedemann; besides, he described *Hughmilleria phelpsae* and *Pterygotus? vernonensis*. According to Chadwick (1919, p. 152), who announced the discovery of the eurypterid horizon, the bed occurred in red Vernon shales probably 40 feet above the Pittsford black shale horizon, which has furnished numerous and abundant specimens of eurypterids. The Vernon eurypterid fauna was reported by Ruedemann to be much like that of the Pittsford shale, and conceivably may, for all practical purposes, be included as part of the latter.

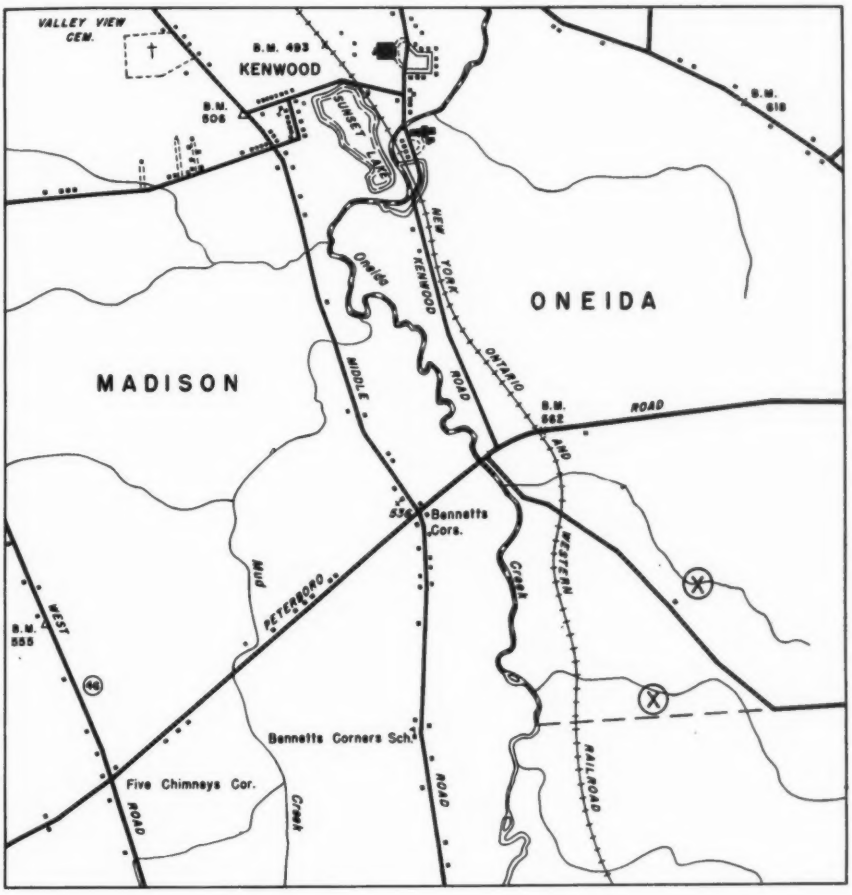
The eurypterids herein described, however, occur in the middle part of the Vernon shale, probably over 200 feet above the base. According to Wayland-Smith (personal communication, Sept. 20, 1954) the single, thin, fossiliferous bed occurs on the banks of two small streams flowing down the east side of the valley of Oneida Creek in the southwest corner of the township of Vernon, Oneida County, New York; that is, about two miles southeast of Kenwood, New York. The two localities are about a quarter of a mile apart (see map, Text-fig. 1). The two streams reveal a continuous section through approximately 300 feet of Vernon shale, although the contact with the underlying Lockport is concealed, and the overlying contact with the Camillus is difficult to locate. However, Wayland-Smith estimates the Vernon as being approximately 400 feet thick, of which the lower 100 feet are concealed. The eurypterid horizon occurs almost exactly in the middle of the exposed section, and it is 21 inches thick and grades from greenish-drab in the lower 2 inches through 4 inches of dark-gray to 15 inches of gray-green, hard, dolomitic shale ("shaly waterlime").

The beds immediately above and below the eurypterid bed were measured by Wayland-Smith and are as follows:

Feet	*Inches*	
55	0	Typical Vernon red shale, with characteristic large (25–35 mm.) circular, green spots. Irregularly stratified in the lower 2 or 3 ft., unstratified above.
3	1	Mottled red and green shale, broken (sun-cracks?) into polygonal sections about 6 inches in diameter with raised edges on upper surface.
1	3	Fissile green shale.
1	9	Fossil (eurypterid and fish) bed.
0	7	Drab, calcareous shale in upper 2 inches; numerous small (2–5 mm. in diameter) perpendicular cavities lined with calcite crystals.
3	5	Green shale, hard and chunky, with many rounded, frosted quartz grains in the lower part; more thin-bedded and shaly, with much less sand, in upper part.
0	5	Pale-green sandstone, very thinly laminated, loosely bound and flexible; weathering into loose sand.
0	10	Mottled, red and green sandstone, hard and compact.
0	5	Red shale.
0	9	Green sandstone—small, rounded quartz grains in a green argillaceous matrix.
1	2	Dark purplish-red shale, fine textured and compact.
76		Mostly thin-bedded, alternating red and green shale with 2 or 3 layers of dark-gray dolomite.
90		Massive, unstratified red shale.

The eurypterids are abundantly represented, all consisting of fragments up to 2 to 3 inches in diameter, and for the most part the fragments are patches of tergites which retain well preserved scale markings of pterygotids. A fragment that may represent the genus *Mixopterus* was noted. Parts of the chelicerae and the gnathobase part of the swimming legs, however, were found, and these indicate two distinct new species of *Pterygotus*, which are described in the following paragraphs. The bulk of the material, therefore, is not specifically identifiable as most of it comprises parts of the tergites of the two species described.

The two pterygotids from the Vernon shale are different from those in the Bertie waterlime above and from the basal Vernon or Pittsford assemblages. In the basal Vernon bed, Ruedemann (1920, p. 205)



TEXT-FIG. *1*—Map of southwestern corner of Oneida County, New York, showing eurypterid localities (marked by X's). Scale 1:31,680.

described *Pterygotus? vernonensis*, a peculiar form with a square dorsal shield in which the lateral eyes occupy the antero-lateral corners. The two forms described herein would normally have a dorsal shield which is rounded on the anterior margins, and therefore comparison with the former, if it is a *Pterygotus*, is dispensed without further comment. *P.? vernonensis* Ruedemann may be closer to *Slimonia* than *Pterygotus*.

The eurypterid horizon has also yielded a most interesting and unusual cyathaspid fish assemblage which Flower and Wayland-Smith (1952) have described. According to these authors (1947), the fossil layer, one foot and nine inches thick, has yielded "several hundred specimens of invertebrate fossils, including abundant pelecypods (*Pterinea*, *Modiolopsis*, and *Nuculites*), abundant but extremely fragmentary eurypterids of the genera *Hughmilleria* [mistaken identification] and *Pterygotus* [subject of the present paper], ostracods, several poorly preserved nautiloid cephalopods, including one brevicone and several orthoconic genera, brachiopods representing the genera *Lingula*

and *Camarotoechia*, an annelid jaw, and a single large siphonophore." Clearly, as noted by these authors, this assemblage is a marine biota in general similar to those of the underlying Pittsford shale and the overlying Bertie waterlime.

The writers wish to express their gratitude to R. H. Flower and R. Wayland-Smith for placing the specimens at their disposal, and to Winifred Goldring and Clinton Kilfoyle of the New York State Museum for the loan of the material.

Family PTERYGOTIDAE Clarke and Ruedemann, 1912
Genus PTERYGOTUS Agassiz, 1845
PTERYGOTUS (PTERYGOTUS) WAYLAND-SMITHI Kjellesvig-Waering & Caster, n. sp.
Text-fig. 2a-c, 2h

The species is based on three free rami of the chelicerae, each of which retains its counterpart, and the gnathobase of the coxa of a swimming leg. Preservation of the material is good, and most details are discernible. The holotype (Text-fig. 2a) is particularly well preserved, having nearly all of the teeth in place and retaining most of the free ramus, except the base. A paratype (Text-fig. 2b) retains only the central portion of the free ramus but reveals the teeth in considerable detail. Another paratype (Text-fig. 2c) is complete, having the articulatory base as well as the distal end preserved; however, except for the larger and more diagnostic teeth, the smaller are either covered or have been broken out.

The free ramus is relatively stout with an unusual number of nearly upright, curved teeth. It is gently curved at the outer margin and ends in a thick, upright, curved spine. The principal or central tooth (1) is very stout and rather blunted, and it is situated midway on the ramus. Anterior to this tooth are two large upright teeth (6 and 7) which, like the central tooth, bend slightly posteriorly.

Posterior to the central tooth (1) is a similar, upright, somewhat backwardly curved tooth (4) of the same size as the two anterior ones (6 and 7). This series is about two-thirds as long as the central one. In between the teeth of this secondary series are a number of irregular-sized teeth of various thicknesses. Of particular diagnostic value is a slender spear-shaped tooth (2) directly posterior to the main central tooth. Another diagnostic tooth (3) is also spear-shaped, approximately the same size as the previously described tooth, and equidistant from the central (1) and the prominent (4) posterior tooth. A large tooth, and probably others, occur on the posterior articulatory part of the rami. A peculiar large tooth, hitherto unknown, occurs adjacent to the terminal tooth but in a different plane than the other teeth (Text-figs. 2, 2a). All teeth are striated.

The ramus is complete in only one specimen (Text-fig. 2c). At the posterior margin of the curved articulatory area, are five small ridges which served as the attachment for the strong adductor muscles.

The fixed ramus ends in a backwardly directed tooth with a slight protuberance at the end of the stem of the ramus. All the teeth are marked with numerous striations.

A specimen of the gnathobase (Text-fig. 2h) of the coxa of a walking leg, which may belong to this species, retains only the anterior larger teeth. These are curved, long, and slender, and the largest is the second from where they decrease in size. Each is striated. The first tooth measures 4.4 mm. in length.

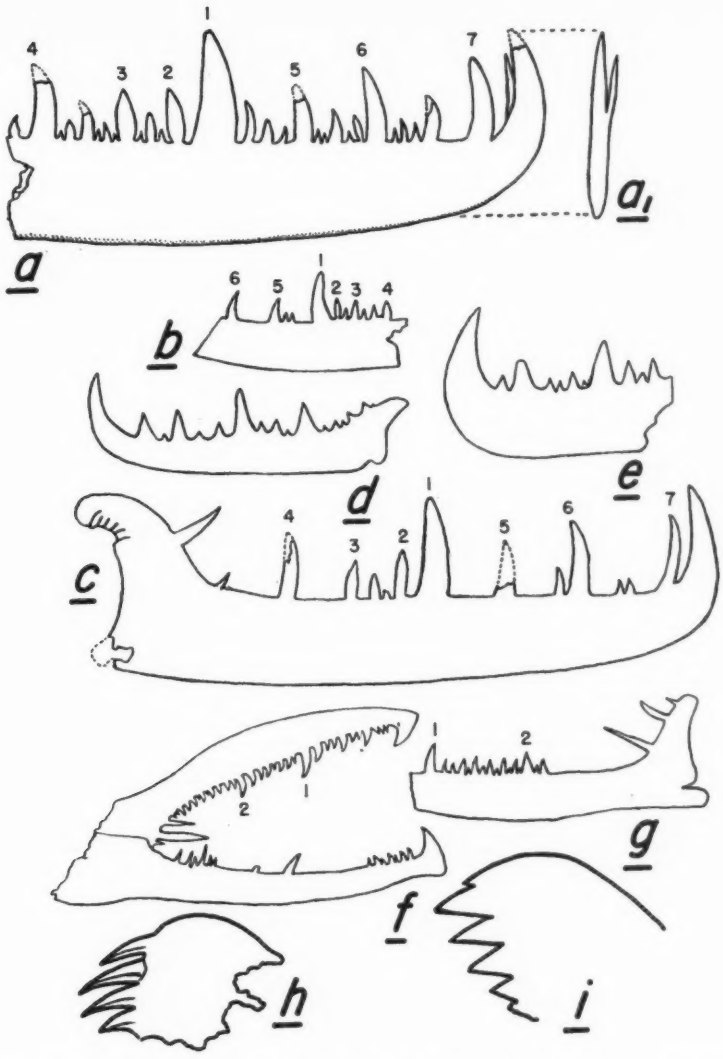
Length of complete ramus (Text-fig. 2c), 64.0 mm.

Length of central tooth, 9.3 mm, width at base, 3.8 mm.

Horizon and locality.—Middle Vernon shale, in the southwestern corner of Vernon township, near Oneida, Oneida County, New York (see map, Text-fig. 1).

Depository.—Holotype is registered under No. 10707, a and b; paratype (Text-fig. 2c) registered under No. 10708, a and b; paratype (Text-fig. 2b) registered under No. 10709, a and b; and paratype (Text-fig. 2h) registered under No. 10714 in the New York State Museum, Albany, New York.

Remarks.—The species has been named in honor of its discoverer, Mr. R. Wayland-Smith of Oneida, N. Y. It is a very distinct species and differs considerably from other forms. It is entirely different from *Pterygotus* (*Pterygotus*) *monroensis* Sarle from the underlying Pittsford shale and from *Pterygotus*



TEXT-FIG. 2—*a*, Free chela of holotype of *Pterygotus* (*P.*) *waylandsmithi* Kjellesvig-Waering & Caster, n. sp. (N.Y.S.M., 10707), ×1⅓; a_1, anterior view of same specimen showing distal, diagonal tooth, ×1⅓. *b*, Free chela of same species (N.Y.S.M., 10709), ×1⅓. *c*, Complete free chela of same species (N.Y.S.M., 10708), ×1⅓. *d*, Free chela of *P.* (*P.*) *cobbi* Hall, after Clarke & Ruedemann, ×⅓. *e*, Free chela of *P.* (*P.*) *monroensis* Sarle, after Sarle, ×⅔. *f*, Chelicera of holotype of *P.* (*Acutiramus*) *floweri* Kjellesvig-Waering & Caster, n. sp. (N.Y.S.M., 10712), ×2⅔. *g*, Free ramus of same species (N.Y.S.M., 10713), ×2⅔. *h*, Anterior part of gnathobase of walking leg of *P.* (*P.*) *waylandsmithi?* (N.Y.S.M., 10714), ×1⅓. *i*, Anterior part of gnathobase of swimming leg of *P.* (*P.*) *floweri* (N.Y.S.M., 10710), ×$\frac{9}{10}$.

(*Pterygotus*) *cobbi* Hall and *Pterygotus* (*Pterygotus*) *juvenis* Clarke & Ruedemann from the overlying Bertie waterlime. In particular it differs from *Pterygotus cobbi* Hall in having the stem of the chelicerae much thicker, and in the far greater number of teeth. The distal end is more strongly curved, and the principal teeth are noticeably larger. The distal side tooth and the shape of the articulatory base of *P. wayland-*

smithi are differences which also distinguish it from *P. cobbi*. The same differences will serve to differentiate the former from *P. juvenis* Clarke & Ruedemann.

In comparison to *Pterygotus* (*Pterygotus*) *monroensis* Sarle, the much slenderer more strongly curved teeth of *P. waylandsmithi* constitute the main differences. It is not as stocky as *P. monroensis*, and the latter also lacks the diagonal penultimate tooth.

PTERYGOTUS (ACUTIRAMUS) FLOWERI
Kjellesvig-Waering & Caster, n. sp.
Text-fig. 2f, g, i

Like *Pterygotus waylandsmithi*, this form is a very distinct species which cannot be confused with any other representative of the subgenus. It is based primarily on a small nearly complete chelicera retaining the complete fixed and free rami and part of the palm (see Text-fig. 2f); this specimen has been designated the holotype (N. Y. State Museum, 10712). A paratype comprises most of the free ramus (Text-fig. 1g), and another paratype retains part of the gnathobase of the coxa of the swimming leg (Text-fig. 2i).

The free ramus is slender, with a large backwardly directed terminal tooth. The ramus thickens at midsection and narrows slightly towards both extremities. In general, the teeth are very small. The largest on the stem of the ramus is a backwardly curved central tooth. At the base of the ramus, however, are at least two long straight teeth, which are longer than the ramus. The rest of the teeth are small and are crowded on the ramus; all are somewhat curved backward, except the distal teeth, which are obliquely turned anteriorly.

The fixed ramus is much slenderer, and the large obliquely turned tooth, customarily present in species of subgenus *Acutiramus*, is represented by a small obliquely turned central tooth. The rest of the teeth on the ramus have not been completely preserved; however, those that are present reveal that all are small and curved backwardly. The posterior teeth appear slenderer and longer than the anterior ones.

The gnathobase of the coxa of the swimming leg (Text-fig. 2i) reveals prominent, nearly triangular teeth; the first of these is the largest and the others decrease in size progressively. The large first tooth shown in Text-figure 2i (10710) is composed of two fused teeth, a condition that may not be of diagnostic value. The first tooth measures 7.3 mm. in length.

Length of holotype, 20.5 mm.

Width of free ramus at midsection, 2.3 mm.

Width of fixed ramus at midsection, 1.8 mm.

Horizon and locality.—Middle Vernon shale in the southwestern corner of Vernon township, near Oneida, Oneida County, New York (see map, Text-fig. 1).

Depository.—All specimens are in the New York State Museum. Holotype (Text-fig. 2f) is registered as 10712, paratype (Text-fig. 2g) as 10713, and paratype (Text-fig. 2i) as 10710.

Remarks.—The species has been named in honor of Dr. R. H. Flower of the New Mexico Institute of Mining and Technology. This form differs from all other species of the subgenus *Acutiramus* in the poor development of the principal teeth which in species such as *Pterygotus cummingsi*[1] Grote & Pitt and *Pterygotus macrophthalmus* Hall, from the overlying Bertie waterlime, have this tooth developed as massive long serrated structures. The subgenus is unknown from the underlying Pittsford shale and therefore comparison is not possible.

It may be noted that the two chelicerae of *P. floweri* are small and therefore may be immature and not have the central teeth developed as other forms have. However, a small chelicera from the Florida Silurian (Kjellesvig-Waering, 1955, pp. 296–297) has the oblique central tooth greatly devel-

[1] This form has previously been known as *Pterygotus buffaloensis* Pohlman (1881, p. 17). However, *P. cummingsi* Grote & Pitt (1875, p. 18) clearly has priority. The latter was described on the basis of a gnathobase by Grote & Pitt, but Clarke & Ruedemann (1912, p. 363) considered it improper or "fatuous," to base a species on that structure and therefore used Pohlman's *P. buffaloensis* as the correct name. In the present writer's opinion there is no question that Grote & Pitt's gnathobase represents the forms now known as *P. buffaloensis*, and furthermore Grote & Pitt were within their rights in naming a species on the structure involved. This structure is now well-known, and therefore the name *P. cummingsi* Grote & Pitt (1875) supercedes the name *P. buffaloensis* Pohlman (1881) and must be used.

oped. This form is *Pterygotus (Acutiramus) suwanneensis* and is much closer to *P. cummingsi* and *P. macrophthalmus* than to *P. floweri*. It is of interest, and perhaps of stratigraphic significance to determine if the large oblique cheliceral teeth of *Acutiramus* developed in the interim between the Vernon fossil bed described here and the overlying Bertie waterlime.

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A SAUROPOD DINOSAUR FROM COLOMBIA[1]

WANN LANGSTON, JR., AND J. WYATT DURHAM

National Museum of Canada, Ottawa; University of California, Berkeley

With the exception of the Upper Cretaceous titanosaurs of Argentina, sauropod dinosaurs are practically unknown in South America (for a summary of known occurrences see the accompanying table). Until recently (Price, 1947) they had not been reported north of São Paulo, Brazil, and hitherto only one Jurassic sauropod has been described (Cabrera, 1947). Thus even fragmentary occurrences of these giant dinosaurs are important as suggesting promising areas for further exploration.

During the course of field work for the Tropical Oil Company in 1943, one of us (Durham) accompanied by Mr. B. B. Colley collected a mid-thoracic vertebra of a sauropod dinosaur near La Paz, Colombia. This is the most northerly occurrence of the Sauropoda in South America (Cretaceous carnivorous dinosaurs have recently been recorded from Colombia, Langston, 1953).[2] The locality (Univ. Calif. Mus. Pal. loc. V-4309) is about 10.5 km. east of La Paz, on the La Paz-Manaure road, César Valley, Department of Magdalena, Colombia (unadjusted coordinates based on the Bogotá observatory, 642.3 km. N., 110 km. E.). The precise point is 650 meters east of the contact (apparently a fault) between the marine Cretaceous limestones on the west and the non-marine sediments on the east as exposed along the road, and about 120 meters due north of the road, on a hillside at an elevation of about 46 meters above the road. This is some 300 meters northwest of the point where the road crosses a large, deep quebrada.

The vertebra was imbedded in a coarse conglomerate comprised of well-rounded quartzite pebbles in a calcareous sandstone matrix. The conglomerate is one of several such beds in an apparently nonmarine

[1] Contribution from the Museum of Paleontology of the University of California.

[2] Botero (1937), in a brief review of the fossil vertebrates of Colombia figures what he believed to be dinosaur teeth. One of these (fig. 64) from the Cretaceous of Huila is probably a badly worn crocodilian tooth. The second specimen from the Cretaceous of Tolima (fig. 65) is as likely to be a large alligator tooth, to judge from the very poor illustration. According to Botero, Santiago Cortés has recognized dinosaur teeth in Colombia, but the reference is not cited and we have been unable to locate the report.

TABLE 1.—SAUROPOD DINOSAURS OF SOUTH AMERICA

Name	Record	Principal localities	Age	Remarks	References
Titanosaurus australis Lydekker.	Practically entire skeleton except skull.	Cinco Saltos (Rio Negro), Neuquén (Neuquén), Argentina; (São Paulo), Brazil.	Senonian	A small moderately heavy sauropod with general proportions of *Camarasaurus lentus*.	Lydekker, 1893
Titanosaurus robustus Huene	Partial vertebral column, limbs, girdles.	Cinco Saltos, Rancho de Ávila (Rio Negro), Argentina.	Senonian	A little larger than *T. australis* but of heavier build.	Huene, 1929a
Titanosaurus (?) *nanus* Lydekker	A few dorsal and cervical vertebrae.	Neuquén (Neuquén), Argentina.	Senonian	Species of doubtful validity.	Lydekker, 1893
Laplatasaurus araukanicus Huene	Partial vertebral column, remainder of skeleton except skull.	Cinco Saltos, Rancho de Avila (Rio Negro), Argentina; Palmitas, Uruguay.	Senonian	A slender-limbed sauropod at least a third larger than *T. australis*.	Huene, 1929a, b
Antarctosaurus wichmannianus Huene	Practically entire skeleton except dorsal and anterior cervical vertebrae.	General Roca (Rio Negro), Sierra de San Bernardo (Chubut), Argentina; Palmitas, Uruguay.	Senonian	A moderately heavy sauropod about the size of *Apatosaurus*.	Huene, 1929a, b
Antarctosaurus giganteus Huene	Caudal vertebrae, femur, pubis.	Aquada del Caño (Neuquén), Argentina.	Senonian	The largest known dinosaur.	Huene, 1919a
Argyrosaurus superbus Lydekker	Caudal vertebrae, most of limbs, manus.	Neuquén (Neuquén), Pampa Pelada, Colhué and Haupí Cado del Rio Senguer, Sierra de San Bernardo (Chubut), Rio Leona (Santa Cruz), Meseta Artigas (Entre Rios), Argentina; Palmitas, Uruguay.	Senonian and "Upper Cretaceous"	A very massive sauropod larger than *Apatosaurus*.	Lydekker, 1893; Huene, 1929a
Campylodon ameghinoi Huene	Maxilla, teeth.	Sierra de San Bernardo (Chubut), Argentina.	Senonian	Might pertain to any South American sauropod except *Amygdalodon* or *Antarctosaurus*.	Huene, 1929a
cf. "*Macrurosaurus*"	Caudal vertebrae.	Cinco Saltos, Rancho de Ávila, Cañadon de Velleche (Rio Negro), Argentina.	Senonian	An European genus very doubtfully recognized in South America.	Huene, 1929a
Microcoelus patagonicus Lydekker	A dorsal vertebra and referred caudal vertebrae and humerus.	Neuquén (Neuquén), Argentina.	Senonian	Genus of doubtful validity.	Lydekker, 1893
Titanosaur	Median caudal vertebra	Barretos (São Paulo), Brazil.	?Cretaceous	Called *Thoracosaurus bahiensis* Marsh by Pacheco	Pacheco, 1913
"Sauropod"	Caudal vertebrae.	Ilha do Livramento (Maranhão), Brazil.	Probably Cretaceous	Large undescribed sauropod	Price, 1947
"Sauropod"	Not stated, presumably fragmentary.	Mongabeira (Minas Gerais), Brazil.	Not stated	Large undescribed sauropod	Price, 1947
"Sauropod"	Not stated, presumably fragmentary	Cuiabá (Mato Grosso), Brazil.	Not stated	Large undescribed sauropod.	Price, 1947
Clasmodosaurus spatula Ameghino	A tooth	Patagonia Argentina	"Upper Cretaceous"		Ameghino, 1898
Amygdalodon patagonicus Cabrera	A few cervical dorsal and caudal vertebrae, pubis, scapula, teeth.	Sierra de Pampa de Agnía (Chubut), Argentina.	Middle Jurassic	A massive sauropod larger than *T. australis;* the only certainly Jurassic dinosaur from South America.	Cabrera, 1947
Present Specimen	Anterior thoracic vertebra	La Paz (Magdalena), Colombia.	Pre-upper Aptian, possibly Jurassic	Sauropod of moderate proportions.	Present paper.

sequence of predominately olive-green to brown clastic sediments which carry a few thin limey lenses. Occasional bits of petrified wood were encountered in these sediments.

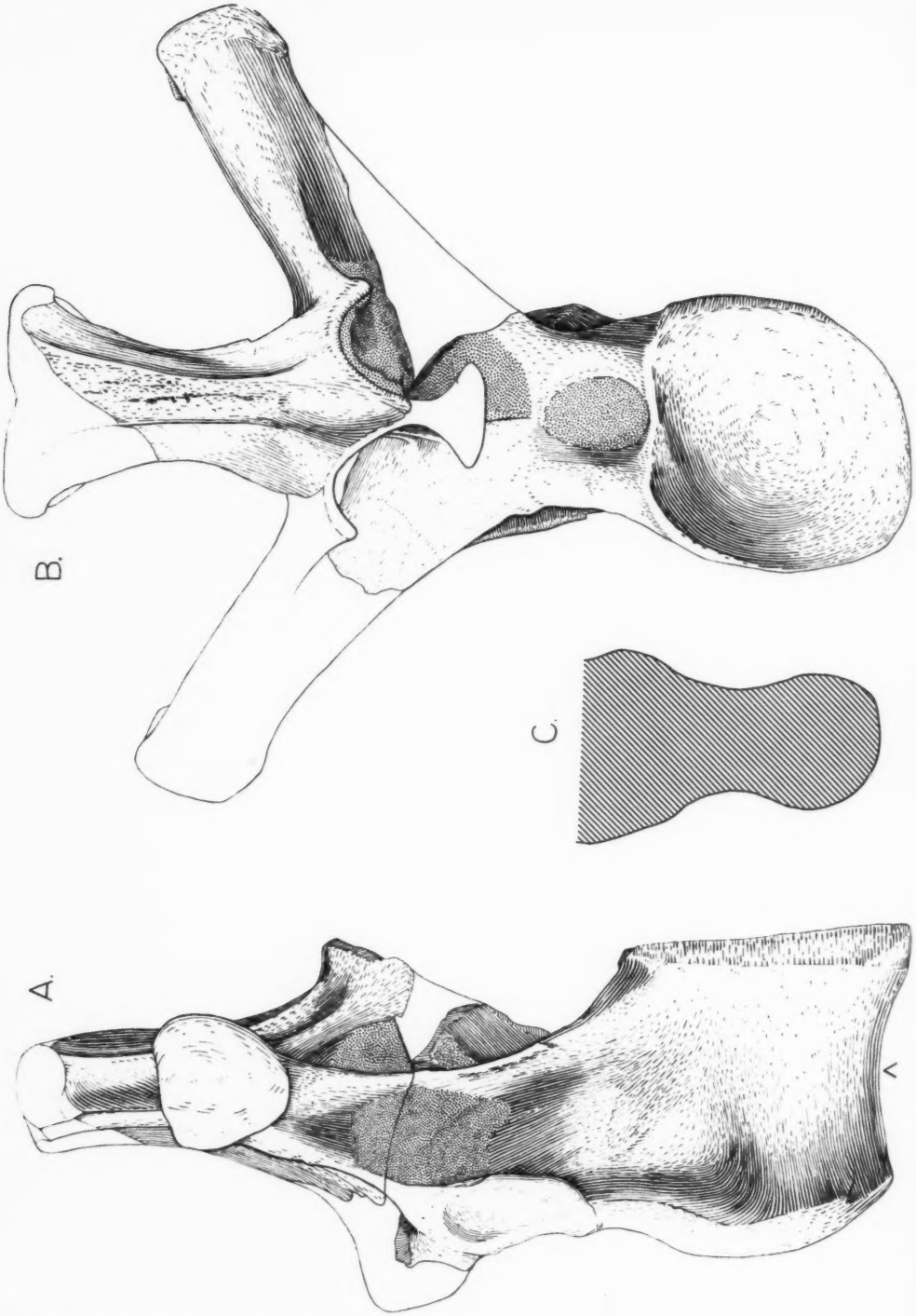
Barring unnoted structural complications the dinosaur-bearing conglomerate appears to be less than 100 meters stratigraphically below the base of the marine limestones and shales that are found in normal superposition 2.5 kilometers eastward along the road. The olive-colored beds were found to crop out only in a limited area so the precise relationships of the dinosaur bed to the characteristic "Giron"-type redbeds a kilometer or so south were not determined with certainty. However, the redbeds usually occupy this stratigraphic position elsewhere in the region and the two appeared to be lateral equivalents of each other. At the eastern contact with the overlying marine beds, less than ten meters of the light-gray, coarse-grained, feldspathic Rio Negro sandstone are present. This small thickness of Rio Negro sandstone is characteristic of the northern shelf area of the Cretaceous geosyncline in which the dinosaur locality is situated, although some 60 kilometers southward along the mountain front, in the trough of the geosyncline, the same formation is immensely thicker.

The "Giron"-type redbeds of this region are generally assumed to be of Jurassic age for they overlie probable Triassic sediments in the Sierra Nevada de Santa Marta (Trumpy, 1943), while in the vicinity of Becerril, 70 kilometers south of Manaure, Lower Cretaceous Barremian ammonites (*Pulchellia*) occur in the lower part of the overlying marine section, with 500 to 1,000 meters of nonmarine Rio Negro sandstone intervening above the redbeds. Throughout the region there is a well marked unconformity between definite redbeds and the Rio Negro formation, the basal unit of the Cretaceous sequence, which is marine above the Rio Negro. The olive-colored beds of the La Paz-Manaure area appeared to be below this unconformity.

In the La Paz-Manaure area the ammonite *Cheloniceras* was found about 100 meters above the base of the marine Cretaceous, and the large foraminiferan *Orbitolina texana* was encountered some 100 meters higher. These fossils suggest that the base of the marine section could be as young as upper Aptian in this area although, as noted above, some 70 kilometers southward it is at least as old as Barremian. If the unconformity at the base of the Rio Negro sandstone is assumed to be the same age everywhere, the dinosaur beds would be of pre-Barremian age at least; some broad regional considerations (for instance, the occurrence of Valanginian ammonites in the lower part of the marine sequence in the Magdalena Valley) suggest even a pre-Cretaceous age. Locally at least it is certain that the dinosaur-bearing rocks are pre-upper Aptian in age.

The vertebra, number 37689 in the Museum of Paleontology of the University of California (Berkeley), lacks the left transverse process, and when found was broken in two sections. No contact exists between the centrum and neural arch, and the neural spine and transverse process, but it is unlikely that much of the bone has been lost from the broken surfaces.

For a sauropod, the bone is of modest size; the centrum is 180 mm. long, 165 mm. high and 154 mm. wide. The total height of the specimen was probably about 525 mm. of which about 165 mm. belonged to the neural spine. From below the centrum is spool-shaped, but in this aspect the sides do not appear sharply constricted; flaring of the ends of the centrum though considerable is gradual. Anterodorsally the sides of the centrum are excavated, but nothing like the characteristic sauropod pleurocoelsis developed. The neural arch and centrum are united without trace of suture. The pedicle is about three-fourths as long as the centrum with its major concavity in outline posterior. The neural canal is large, higher than wide and evidently descends some distance into the centrum in the middle. The neural arch is a little higher than the centrum. The centrodiapophyseal, supradiapophyseal, and suprapostzygapophyseal laminae are well developed and bound deep sulcae. They tend to thicken at the edges but are in places almost paper-thin. There is an indication of fenestration at the base of the neural spine between the paradiapophyseal and supradiapophyseal laminae. The moderately long transverse process projects outward and upward at an angle of 45 degrees. Terminally it is massive and club-like, but toward the arch it branches into the various



TEXT-FIG. *1*—Thoracic vertebra of a sauropod dinosaur from Colombia; U.C.M.P., 37689; ×¼. A, from the left side (neural arch and spine drawn reversed from right side); B, from behind; C. vertical transverse section through centrum showing absence of true pleurocoels. Drawings by Joan Sischo.

supporting laminae. The tubercular surface is convex in all directions. The parapophysis is large, more than twice as high as wide and lies wholly on the side of the neural arch; below it the anterior centroparapophyseal lamina is massive, but very short. Postzygapophyses are strongly arched and transversely narrow rather than flat and wide as in many sauropods. Prezygapophyses are not preserved. Judging from its preserved base the hyposphene was moderately developed. The neural spine is massive and of moderate height being about intermediate between middorsal spines of *Camarasaurus* and *Diplodocus* and about as high as the centrum. It is incomplete at the top, but probably little is missing. As far as preserved the spine is undivided and a termination like that of posterior dorsals of *Diplodocus* can be inferred with confidence.

The roughened prespinal ridge lies in a deep trough bounded laterally by the suprazygapophyseal lamina on either side. The ridge widens above. The pre- and postspinous laminae join at the top of the spine.

The Colombian sauropod is strikingly different from the Cretaceous *Titanosaurus* and *Laplatasaurus* in the absence of true pleurocoels. This condition is unusual in sauropods generally, but the cavities are hardly if at all developed in the African Jurassic *Dicraeosaurus*, in *Amygdalodon patagonicus* from the Jurassic of Argentina, and perhaps even in the North American Jurassic *Camarasaurus annae*. However, the Colombian vertebra (probably an anterior thoracic to judge from the nature and position of the parapophysis) differs importantly from *Dicraeosaurus* in having a relatively simple, and massive neural spine. From *Camarasaurus annae* (known only from a very forward thoracic vertebra) it differs in the much more elevated centrum and neural arch, in the relatively higher undivided neural spine, and the strongly arched zygapophyses. The centrum is opisthocoelous in the Colombian sauropod whereas in the only known thoracic vertebra of *Amygdalodon* (probably a more posterior dorsal) the centrum is amphicoelous. In this at least the Colombian animal agrees with *Dicraeosaurus* whose dorsals are more strongly opisthocoelous than in most sauropods, where the centra tend to become flattened or biconcave toward the sacral region.

This specimen is significant mainly because it constitutes the most northerly record of the Sauropoda in South America. The bone itself sheds no light on the precise age of the rocks which yielded it, but sauropod dinosaurs are generally conceded to have evolved no earlier than the beginning of the Jurassic period. As noted above, invertebrate evidence indicates that the dinosaur-bearing rocks are pre-Upper Cretaceous in age. The Colombian animal must then be either a Jurassic or a Cretaceous form. As such it is either the second recorded Jurassic sauropod or the first Lower Cretaceous dinosaur from South America.

Almost certainly the animal is new, but it is impossible even to assign it to a family at this time. Since individual sauropod vertebrae are not very practical as standards of reference, no name is here proposed for the sauropod from Colombia.

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MAZAPHYLLUM, A NEW CYSTIPHYLLID CORAL FROM THE SILURIAN OF NEW SOUTH WALES

KEITH A. W. CROOK
University of Sydney, Australia

INTRODUCTION

The coral *Mazaphyllum* is the first recorded example of a plocoid genus in the suborder Cystiphyllina. Cystiphyllid corals are generally solitary, although some loosely compound forms are known. The discovery of a plocoid form thus adds a further chapter to our knowledge of the suborder and at the same time raises further problems regarding the evolution of the group.

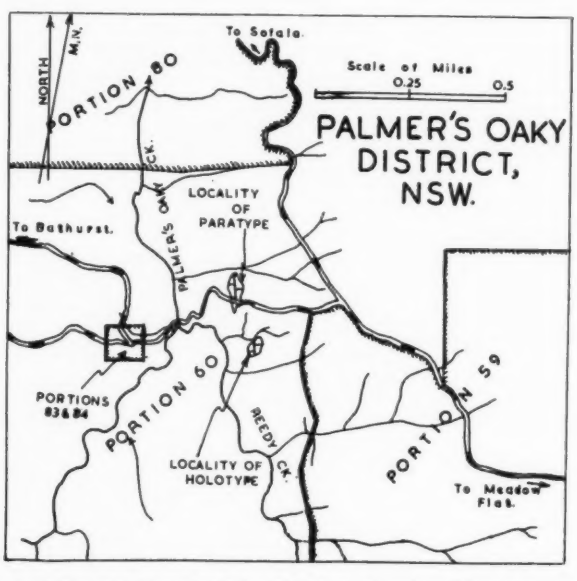
All specimens of *Mazaphyllum* which have been discovered to date can be grouped as one species, and are from limestone lenses in the Palmer's Oaky District, some 28 miles north-east of Bathurst, New South Wales. There are several lenses, of both Silurian and Devonian age, in this region, but only two have yielded specimens of the coral. Both are situated on the eastern slope of the valley of Palmer's Oaky Creek, in Portion 60, Parish Turon, County Roxburgh (Text-fig. 1), and occur in a sequence of shales which grade laterally into andesitic tuffs.

The associated fauna includes such forms as: *Halysites* spp., *Rhizophyllum* sp., *Typlasma lonsdalei* Etheridge, *T. loveni* (Milne-Edwards & Haime)?, *Favosites* spp., *Cystiphyllum* sp., and *Encrinurus bowningensis* Foerste. This assemblage is definitely Silurian, and probably should be placed near the junction of the Lower and Middle Silurian.

SYSTEMATIC DESCRIPTION

Genus MAZAPHYLLUM Crook, n. gen.

Type species.—*Mazaphyllum cortisjonesi*, Crook, n. sp.



TEXT-FIG. *1*—Map of Palmer's Oaky District, showing *Mazaphyllum* localities.

Diagnosis.—Plocoid Cystiphyllina, thamnasteroid, having septa, each of which consist of a single series of discrete acanthine trabeculae, which are never contiguous, and which may pierce several dissepiments. Unique among the Cystiphyllina in being plocoid.

Description.—The corallum is thamnas-

teroid, and is composed essentially of layered dissepimental tissue having tabularia distributed unevenly throughout. The dissepimentaria are generally wide, and are composed of gently arched layers of dissepiments which are nearly horizontal or slightly arched between the tabularia, but are steeply inclined adjacent to the tabularia.

The tabularia consist of many series of tabellae, with rare complete tabulae, all elements being arranged in a vortical pattern, concave upwards.

The septa are confluent, and are represented by single series of discrete acanthine trabeculae, both holacanths and rhabdacanths being present. The trabeculae, which are never contiguous, are initiated on the dissepimental crests and may pierce several dissepiments. They are almost entirely absent from the tabularia.

Relationships.—*Mazaphyllum* bears a superficial resemblance to the only two Silurian plocoid genera yet described, *Arachniophyllum* Dana and *Zenophila* Hill. In both of these the presence of continuous septa, which appear within the tabularia, serves as a distinguishing feature. *Arachniophyllum* is also characterized by the appearance of a three-dimensional trabecular network formed by the development of secondary septal tissue (Lang & Smith, 1927, p. 466). *Zenophila* is further distinguishable by the presence of an aureole of regularly radial septal segments surrounding each tabularium (Hill, 1940, p. 414).

Within the Cystiphyllina, *Mazaphyllum* shares with *Hedströmophyllum* Wedekind and *Holmophyllum* Wedekind the feature of discrete acanthine trabeculae which pierce several dissepiments. Both of Wedekind's genera, however, are simple forms. Although Hill (1940, p. 397) places these two genera in synonomy, Wang (1950, p. 266) separates them, pointing out that *Hedströmophyllum* possesses holacanth trabeculae, whereas *Holmophyllum* possesses rhabdacanths. *Hedströmophyllum* is not known from Australia, but *Holmophyllum* is represented by *H. multiseptatum* Hill, 1940, from Yass. The nature of the trabeculae in this species is indeterminate, but it possesses a horizontal series of dissepiments in the peripheral regions, a feature reminiscent of *Mazaphyllum*. It would appear that there may be some relationship between *Mazaphyllum* and Wedekind's two genera, but the position is complicated by the compound nature of *Mazaphyllum* and the appearance of both types of trabeculae in it.

At present it is not possible to suggest an ancestor for *Mazaphyllum*. Wang (1950) considers *Holmophyllum* to be a derivative of *Tryplasma*, whereas *Hedströmophyllum* is considered to be a derivative of *Cystiphyllum*. The gap between these forms and *Mazaphyllum* is so wide, however, that such inferences are of little help. The fact remains that only two other plocoid corals are known from the Silurian, and there is no apparent relationship of *Mazaphyllum* to either of them.

MAZAPHYLLUM CORTISJONESI Crook, n. sp.
Text-figures 2 3

Diagnosis.—*Mazaphyllum*, having 40 to 50 septa (i.e. a series of trabeculae) disposed radially about each tabularium, these tabularia being 4 to 5 mm. in diameter.

Material.—The holotype (USGD 6136) and the paratype (USGD 6139) are both housed in the Paleontology Museum of the Dept. of Geology and Geophysics, University of Sydney. Several sections were cut from each specimen. Some fragments from the holotype are also in Dr. D. Hill's collection, at the University of Queensland.

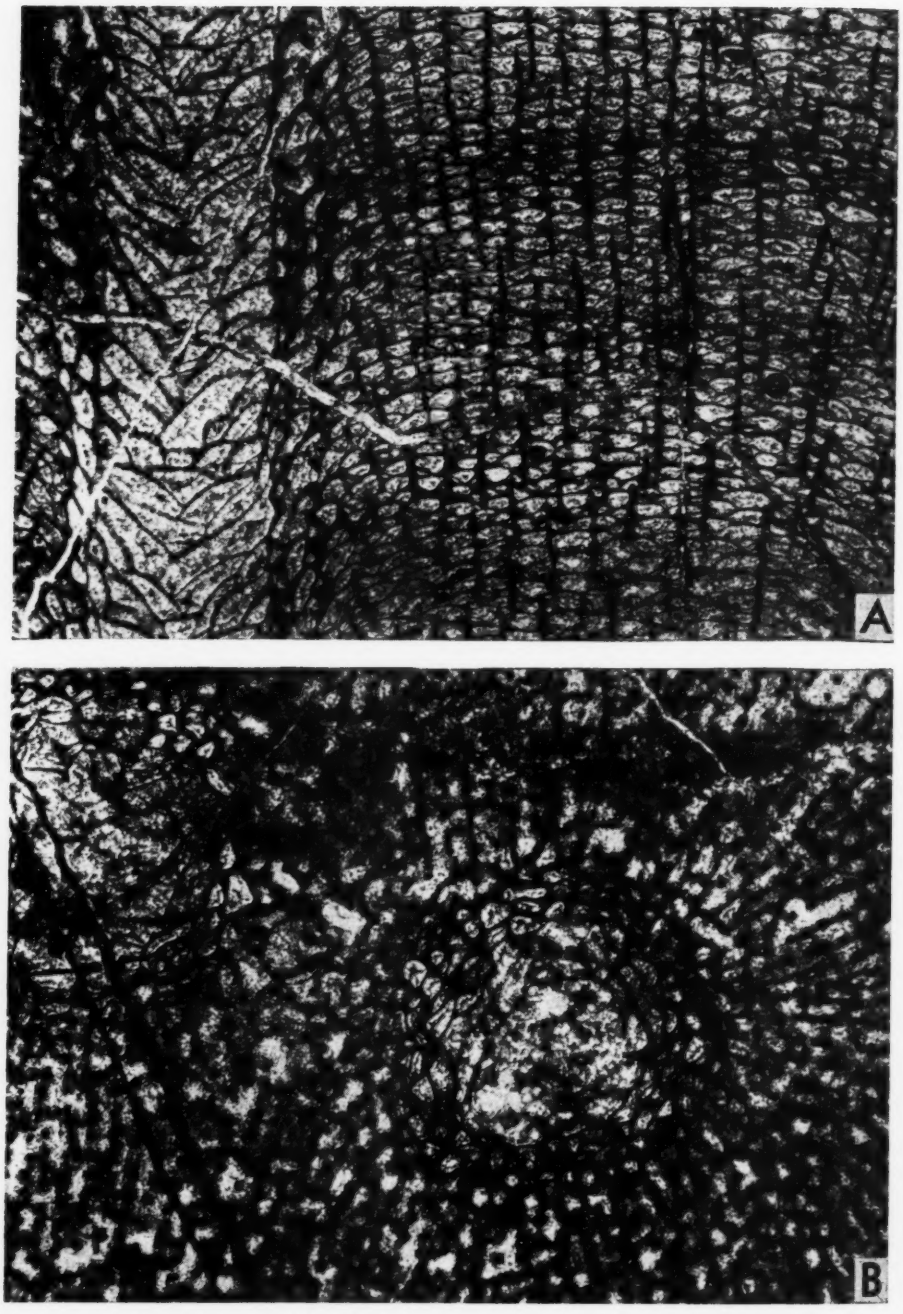
Locality.—Portion 60, Parish Turon, County Roxburgh, New South Wales.

Age.—Silurian, probably near the junction of the Lower and Middle Silurian.

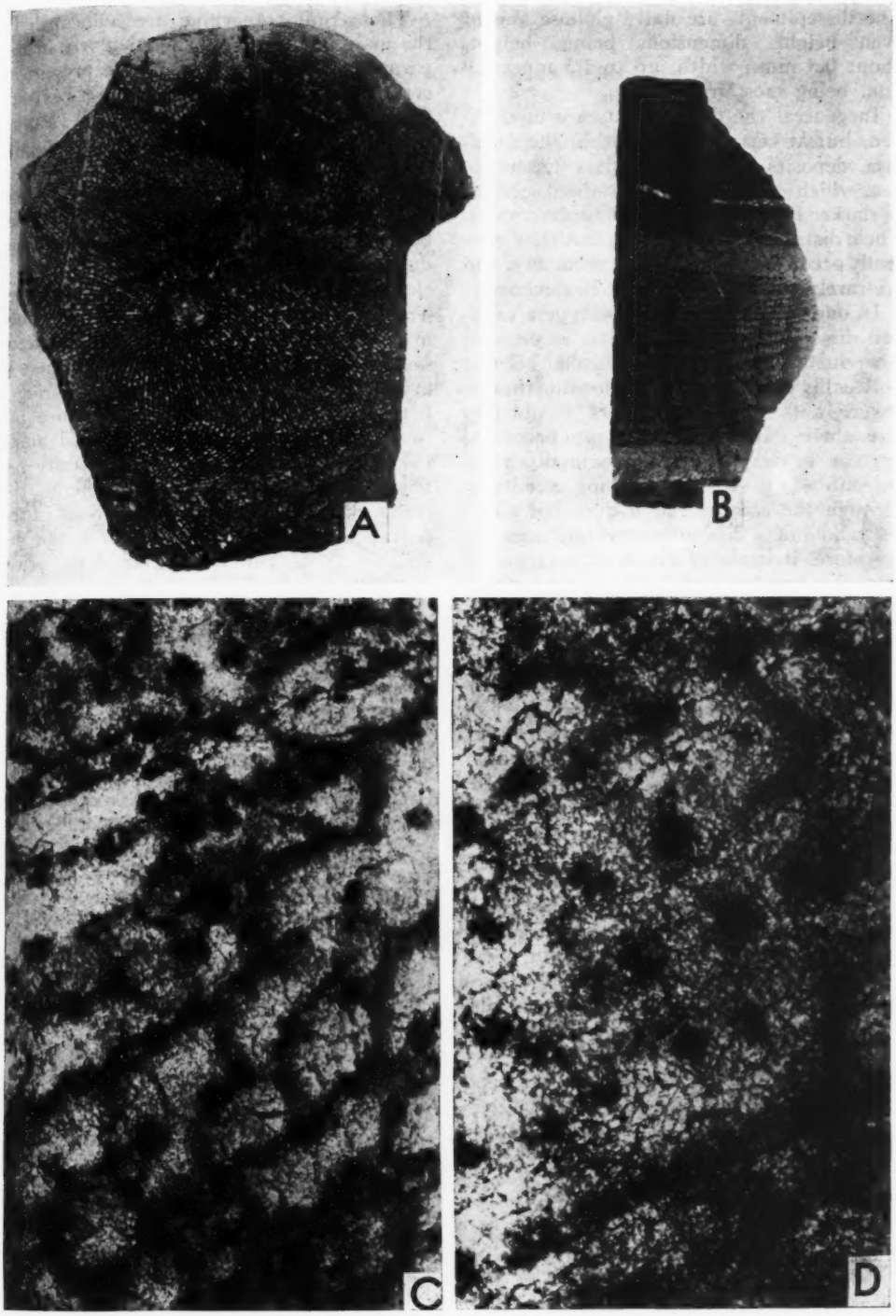
Name Derivation.—Named for H. F. Cortis-Jones, M.B.E., M.A., Emeritus Senior Master of Newington College, Sydney.

Description.—No complete coralla have yet been discovered, but it is evident that they attained considerable dimensions. The dimensions of the preserved portion of the holotype are: 16 cm. by 12 cm. by 5 cm. depth. The holotheca is unknown. On a weathered surface the corallum is fairly smooth, with no apparent peripheral elevations about the tabularia, nor at any points within the dissepimentaria.

The dissepimental layers are fairly constant in thickness, and are gently arched or horizontal except immediately adjacent to the tabularia, where they are inclined at an angle of about 30° to the tabularial axes.



TEXT-FIG. 2—*Mazaphyllum cortisjonesi* Crook, n. gen., n. sp., ×25. Longitudinal and transverse sections through holotype.



TEXT-FIG. 3—*Mazaphyllum cortisjonesi* Crook, n. gen., n. sp. *A*, *B*, Transverse and longitudinal sections through holotype, ×2½. *C*, Transverse section through paratype showing discrete holacanth trabeculae, ×45; *D*, transverse section through holotype showing discrete rhabdacanth trabeculae, ×45.

The dissepiments are flatly globose and of even height, dimensions being: height, about 0.3 mm.; width, up to 1.5 mm., 0.9 mm. being most frequent.

In general the dissepiments are unmodified, but at certain levels within the corallum, deposits of dark secondary tissue appear which stand out in longitudinal sections as darker bands within the dissepimentaria. Their distribution is variable, but they generally occur every 5 to 8 mm. vertically, and are rarely greater than 1 mm. in thickness.

In one section from the holotype a peculiar dissepimental modification is present, wherein the dissepimental walls become noticeably thickened, although not with dark tissue, and the dissepiments completely lose their flatly globose shape becoming angular or trapezoidal. This modification is confined to a zone passing vertically through the corallum, and does not affect the whole of a dissepimentarium; possibly, therefore, it is the result of an injury or a mutation involving the cells in a restricted area.

The tabularia are small and unevenly distributed, diameters varying between 3.0 and 6.5 mm.—the larger values occurring in the distal portions of the corallum. The most frequent diameter encountered is between 4.0 and 4.5 mm. Within the tabularia, tabellae are very well developed; complete tabulae are rare. These elements are vortically arranged; the apex angle is directed proximally between 100° and 110°. The tabellae bear short trabeculae in a few cases. Portions exhibit a definite boundary to the tabularia, marked by the thickening of certain dissepimental crests with a deposit of secondary tissue. In other portions there is no definite boundary and the dissepiments gradually merge laterally into tabellae.

The septal trabeculae are holacanth in the main (Text-fig. 3C), particularly in the paratype, but rhabdacanths are present in certain sections of the holotype (Text-fig. 3D). In general they are 0.06 to 0.11 mm. in diameter, the holacanths showing a dark outer wall, presumably of lamellate sclerenchyme, surrounding a clear, structureless inner mass. The rhabdacanths are simple, bearing 3 to 5 rays, the outer walls being dark, whereas the inner portions consist of a clear amber mass without visible structure. Trabecular height is variable, with values up to 5 mm. These longer trabeculae pierce several dissepiments. In some cases there is evidence of dissepiments acting as bridges between the trabeculae. The distance between trabecular centers, measured along the septa, is variable, but is generally between 0.15 and 0.2 mm. In general, the trabeculae lack interconnecting tissue in the septal plane, but in a few places the development of connecting lamellate sclerenchyme has been observed.

Acknowledgement.—The author wishes to express appreciation for assistance rendered by Dr. Dorothy Hill of the Department of Geology, University of Queensland.

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A NEW TABULATE CORAL FROM NEW SOUTH WALES[1]

J. KERRY FITZGERALD
Bureau of Mineral Resources, Canberra

SYSTEMATIC DESCRIPTION

Genus DESMIDOPORA Nicholson, 1886

Type species.—*D. alveolaris* Nicholson of the Silurian Wenlock limestone at Dudley, England.

DESMIDOPORA MULTITABULATA FitzGerald, n. sp. Text-fig. 1A, B

Diagnosis.—Corallites are small and closely packed, from 0.3 to 0.5 mm. in diameter. The length of mature corallites is about 11 mm. Tabulae are numerous, concave upward, and closely spaced (11 occupy the space of 5 mm.).

Description.—The massive corallum is composed of minute corallites and weathering has made no impression on the surface. The corallites radiate from a central base, as shown in the vertical section. Corallites are variably polygonal in shape, becoming lenticular and lunate. Some calices have become confluent where the wall is incomplete or broken down. This confluence results in meandering shapes in cross section. The corallites are closely packed and vary from 0.3 to 0.5 mm. in diameter. In vertical section as many as 16 corallites occupy a space of 5 mm. The length of the mature corallites is about 11 mm. The walls are thick and usually spongy, although in a few places a primordial wall exists for a few millimetres. The walls fully circumscribe some of the corallites. Mural pores are very distinct, numerous, and small. They usually form two rows with the pores arranged alternatively. Tabulae are complete, numerous, and concave upward, and they are usually about 0.5 mm. apart. Tabulae vary in attitude in the corallites. In some cases they occur at the same level in adjacent corallites. Reproduction is by fission. Vague plates resembling septal spines can be seen in a few cases; these are incomplete tabulae remaining after fission. In the older parts of the corallum, where there is little room for the growth of new corallites, the new individuals only survive for a few chambers.

Remarks.—Comparison of the new species, *Desmidopora multitabulata*, with the other described representative of this genus, *Desmidopora alveolaris* Nicholson, emphasizes the differences in size and shape. *D. alveolaris* has much larger corallites; they are 0.7 to 1.0 mm. in diameter. Those of *D. multitabulata* vary from 0.3 to 0.5 mm. in diameter. The tabulae in *D. alevolaris* are "mostly convex, with their convexities turned upwards, and generally about half the diameter of the corallites apart" (Nicholson 1886, p. 291). In *D. multitabulata* the tabulae are concave and are about twice the diameter of the corallites apart. The walls of the corallites of *D. multitabulata* are regular in thickness. In *D. alveolaris* "thickening of parts of the walls of the corallites is shown in vertical section" (Nicholson 1886, p. 292).

The similarity of *Desmidopora* to her genus *Multisolenia* was noted by Fritz (1939). Sokolov (1947) supports the independence of the two genera but notes the similarity of *Desmidopora* to *Nodulipora* Lindström.

Desmidopora multitabulata is very important in the stratigraphy of the Orange District, New South Wales. *Desmidopora sp.* has been recorded in the Orange District at Four Mile Creek, about 18 miles from this area, by Stevens and Packham (1953). These are the only two recorded instances of the occurrence of the genus in Australia.

Acknowledgments.—The writer is indebted to Professor C. E. Marshall of the University of Sydney for the privilege of publishing this report, and to Mr. D. Haverstein for making the accompanying photographs.

[1] Published by permission of the Director, Australian Bureau of Mineral Resources.

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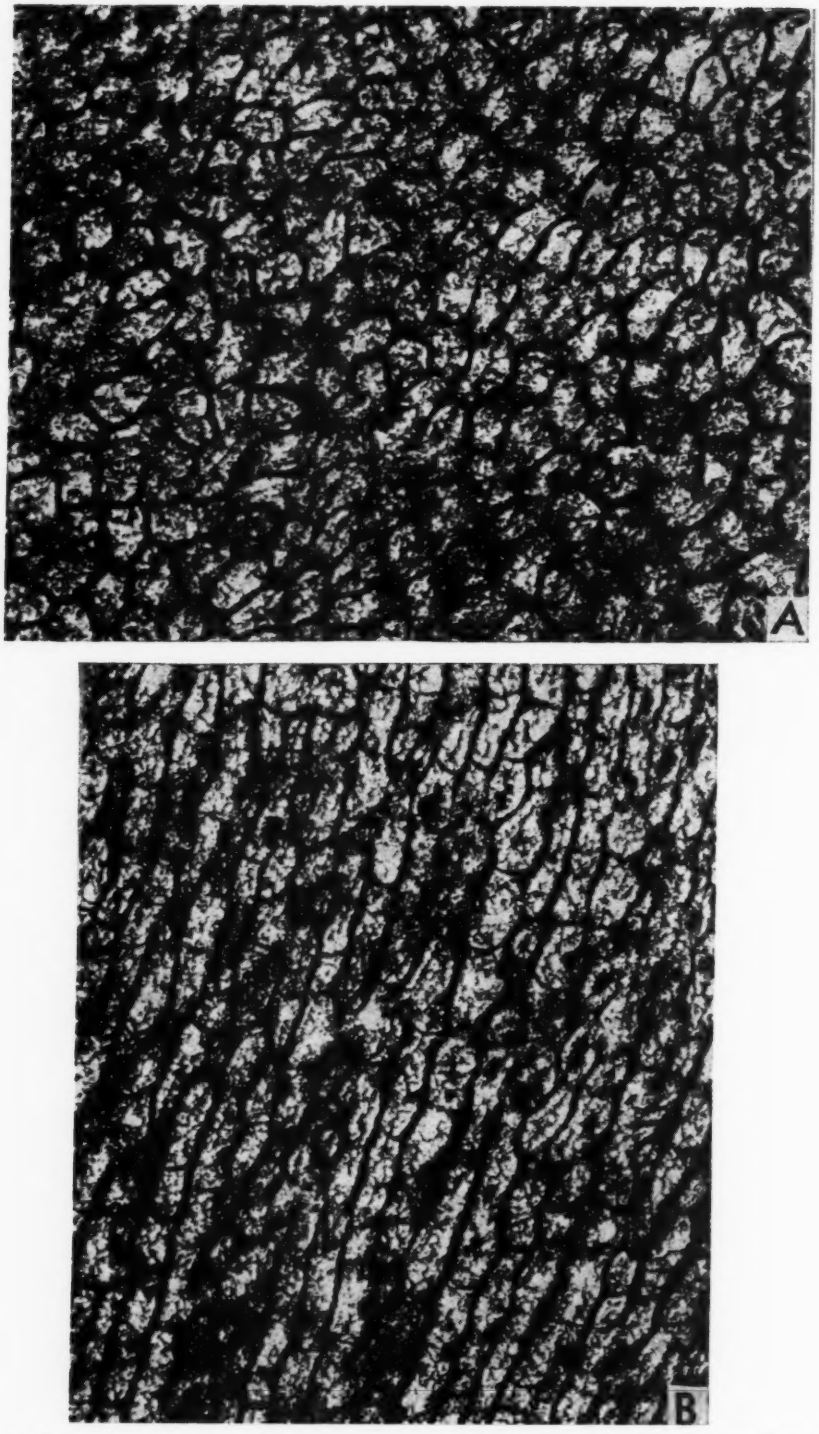

TEXT-FIG. *1*—A, transverse section of *Desmidopora multitabulata* FitzGerald, n.sp., ×15. University of Sydney, 7118. B, vertical section of *D. multitabulata* FitzGerald, n.sp. ×15. University of Sydney, 7118.

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A STUDY OF THE VARIATION OF RECENT AND FOSSIL OSTRACODES

ERHARD M. WINKLER
University of Notre Dame, Notre Dame, Ind.

In numerous cases fossil ostracodes of the same species show many irregularities of size, including the height-length index of their valves, which affects the dispersion. A previous analysis of the Pliocene *Cytheridea pannonica* Mehes of the Vienna Basin, Austria (Winkler, 1947) resulted in observation of large fluctuation of the size of the valves with the change of the environmental conditions. Cooper (1945) studied the moult stages of *Ectodemites plummeri* by plotting length-height dimensions on coordinate paper. The uniform growth rate and the increasing distance of the stages from each other towards the mature animal indicates a clear separation of the adults from younger instars. The height-length index ratios of five species of living and fossil ostracodes were investigated and are compared with each other on a similar basis in the present paper.

About 5000 valves belonging in ten species were measured during the years 1952 and 1954. Techniques of measurement and graphical representation were discussed in a previous paper (Winkler, 1954), but are reported here briefly to explain better the working procedure. The valves were mounted on a glass slide, photographed, and the height-length index ratio measured and calculated. Lengths, heights, and indices of the valves were then plotted on a diagram with the lengths on the abscissa and the heights on the ordinate axis, as shown in the diagram of *Cyprinotus incongruens* of the sample taken March 29, 1952 (Text-fig. 1). The dashed diagonal lines on this diagram are lines of equal indices, as figured from the height-length of the valves; whereas the solid lines between the index lines represent the average index. The number of cases, as illustrated by symbols, is explained in the key of the illustration and give the diagram a three dimensional character. For the purpose of numerical comparison of the dispersion of the various ostracode populations, the "dispersion range" is introduced. It results from the difference of cases from the highest to the lowest index line and excludes about five per cent exceptionally round or oblong valves achieved by possible measuring mistakes or the interference of another species. The dispersion range can be calculated more nearly accurately with the Gauss' method of the smallest squares; however, the simple graphic method used here is sufficient for a visual comparison of the diagrams. Nevertheless, the dispersion range along the abscissa towards younger instars is of but little interest in this paper, because it is due to the presence of instars which originally were not intended to be included.

CYPRINOTUS INCONGRUENS Turner, 1895

Hoff's description (Hoff, 1942) corresponds closely to the available material.

Localities.—A fairly large number of *Cyprinotus incongruens* were obtained from two temporary glacial kettle-hole ponds.

Locality 1: Studebaker Woods on Gertrude Street, about a mile south of the intersection with Ewing Street, a few miles south of South Bend, Indiana. Size of the pond rarely exceeds fifty square yards and three feet in depth, varying with the season. The presence of water plants later in the season has produced a thick layer of muck. The drouth lasting from sum-

mer 1952 to April 1954 caused considerable lowering of the ground water table and thus the disappearance of the whole pond during this time. The ostracode *Cyprinotus incongruens*, together with some *Daphnia* and *Cyclops* make up the fauna of this pond.

Locality 2: Intersection of the highways 20 and 12 about 5 miles east of Michigan City, Indiana. A highway ditch that does not exceed more than 20 square yards in area and one foot in depth. The existence of the pond is restricted to the early spring thaws and rainy season. Its short seasonal life and exposure restricts growth of water plants. *Cyprinotus incongruens*, *Cyclocypris ovum* and some *Cyclops* were the only crustaceans noted. The pH value of both ponds at the time of sampling was close to 5.5.

Variation of average indices and dispersion of the species.—Text-figure 1 pictures *Cyprinotus incongruens* in samples taken from the Studebaker Woods pond on various dates as marked on the diagram. The presence of younger instars is discernible along lines of equal indices. The break between the adult and the younger instars is well defined with the middle diagram dated March 29, 1952.

The following chart compares the lengths, average indices and dispersion ranges of the indices for samples taken in 1952.

According to Hoff, males rarely were observed with *Cyprinotus incongruens*, thus their possible appearance was not further considered. They are smaller in size and would probably be found among the range of smaller instars. The development of the adults was completed by March 1, when the samples were netted below the ice. The sample which was taken four weeks later lacked any adult specimens, for the second generation was apparently on the way at this time. The lengths of the adults remained close to 1.52 mm. without fluctuating greatly, in both generations of the two ponds. The arithmetic means of the indices also proved to be nearly equal; a slight elongation could be observed toward the date of extinction. The sudden increase of the dispersion range just before the disappearance for the season may be the result of degeneration. Detailed studies of additional material would be required to verify this possibility.

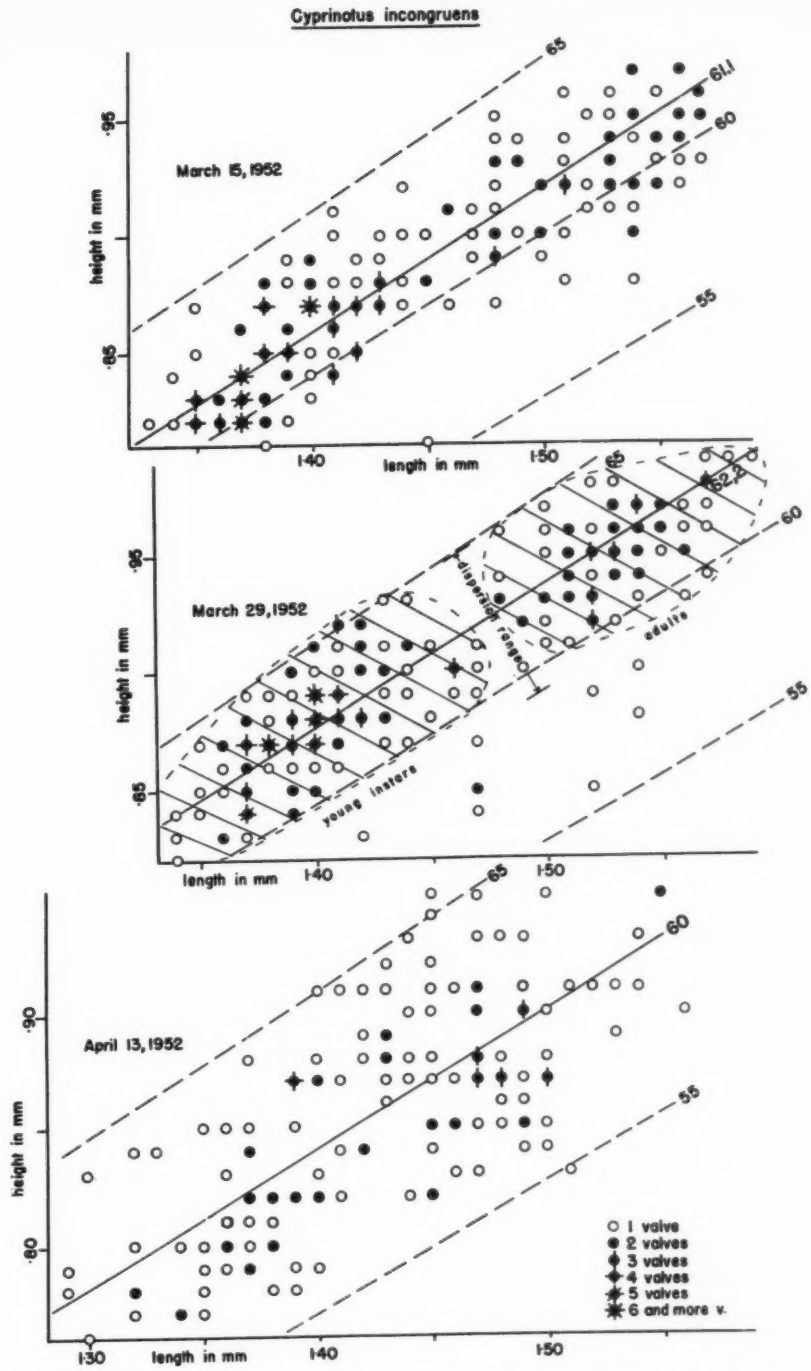
After the one-and-a-half year drouth ending 1954, the Studebaker Woods pond regained its original water level about April 10, 1954. A weekly investigation of the fauna of the pond resulted in the observation of *Cyclops* about a week after the return of the water level to the pond; but adult stages of ostracodes did not show up before the last week in April. Samples of ostracodes were taken from this pond May 1, May 23 and May 30. The measurement of the indices and their morphology failed to indicate the presence of *Cyprinotus incongruens*. No *Cyprinotus* were observed throughout the entire season. Probably the drouth destroyed the eggs entirely, or, the eggs may have hatched at the beginning, and then the lack of water later in the season destroyed the young.

CYPRIA TURNERI Hoff, 1942

Locality.—A pond of a few hundred square yards filled with water through most of the year is located only about 200 yards east of the Studebaker Woods pond previously mentioned. Pond shrubs and weeds are the substrata for a very rich fauna of *Daphnia*, *Cyclops*, *Cypria turneri*, *Cypricercus* sp. and various species of *Candona*. James J. Manion and Lawrence Cory found a large number of *Cypria turneri* in the gela-

Date 1952	Studebaker Woods Pond					Michigan City Pond				
	No. of Cases		Arithmetic Mean		Dispersion Range†	No. of Cases		Arithmetic Mean		Dispersion Range†
	Adult	Young	Adult	All		Adult	Young	Adult	Young	
3/1	48	60	61.1	61.5	59–65(6)	—	—	—	—	—
3/15	87	118	61.0	61.1	58–64(6)	137	63	59.7	61.1	56–63(7)
3/29	92	113	61.7	62.2	59–65(6)	—	204	—	62.5	60–66(6)
4/13	75	88	60.0	60.0	56–65(9)	65	—	60.8	—	57–65(8)

† Excludes obviously erroneous cases, about five per cent of the total.



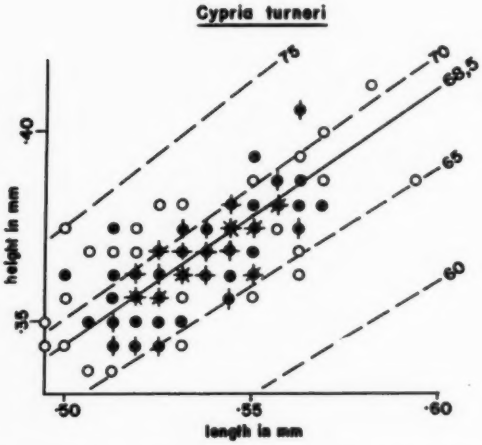
TEXT-FIG. *1*—Distribution chart of the living freshwater ostracode *Cyprinotus incongruens*.

tin of the envelopes of salamander eggs; *Cypria* apparently feeds and hatches in them (Oral communication from Messrs. Manion and Cory and in an unpublished thesis).

DISCUSSION OF THE VARIATION.—Text-figure 2 shows the diagram of a sample taken on March 21, 1954. Another sample had been taken March 29, 1952.

Date	Av. Index	No. of Valves	Dispersion Range
3/29, 52	68.1	112	65–72 (7)
3/21, 54	68.5	160	64–73 (9)

Both *Cypria turneri* faunas are nearly identical. Their irregular dispersion, however, may be traced to the fact that both



TEXT-FIG 2—Distribution chart of the living freshwater ostracode *Cypria turneri*. The key to the illustration is given on Text-fig. 1.

valves were mounted on the slide and thus a number of valves may not have been lying horizontal during measurement. Younger instars are absent in both samples; the association with salamander eggs apparently is restricted to the younger moult stages, but no further information was obtained on the life cycle of *Cypria turneri*.

CYCLOCYPRIS OVUM cf. SHARPEI Furtos, 1933

The author's specimens are very similar to those of Furtos (1933) and Hoff (1942) but exceed them in size.

Localities.—The material for measurement was taken from a bog of a partly-filled kettle lake within the Maxinkuckie morainal belt, about ten miles west of South Bend, Indiana, just 200 yards south of highway 20. The water level of the two-acre open bog barely exceeds three feet and carries reeds. *Cypridopsis vidua*, a few species of *Candona* and *Cyclocypris ovum* cf. *sharpei* populate the bog. The Michigan City pond, as described with *Cyprinotus incongruens*, was populated with *Cyclocypris ovum* in the early spring of 1952.

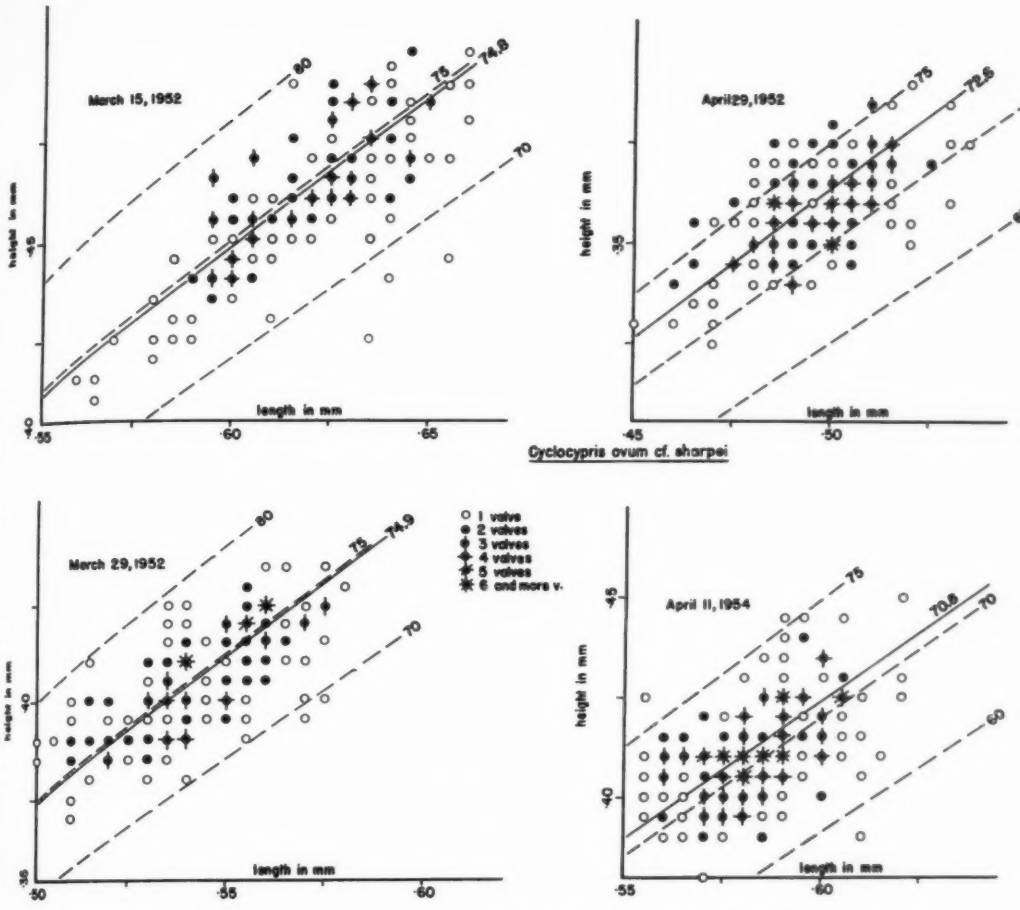
Variation and dispersion range.—The range towards younger instars is very narrow, possibly due to the fact that the moulting stages were passed simultaneously. Here too, the indices tend to show the trend towards greater elongation late in the season, similarly to *Cyprinotus incongruens*. Although the number of generations within one season (March to late April) was not obtained, the sample taken on March 29, 1952, is evidently an early instar of a second generation. The dispersion range is nearly the same in all the samples.

Date	No. of Valves	Av. Lengths	Av. Index	Dispersion Range
3/15, 52	160	0.618	74.8	70–78 (8)
3/29, 52	150	0.509	74.9	70–79 (9)
4/11, 54	203	0.594	70.7	66–75 (9)
4/29, 52	159	0.610	72.6	68–77 (9)

APARCHITES MILLEPUNCTATUS cf. GRANILABIATUS (Ulrich), 1892

The author's material contains a large variety of shapes and surface markings. Muscle spot and papillae along the left ventral margin are distinctly evident in a large number of valves resembling Ulrich's *Aparchites millepunctatus*. Many valves approximate Ulrich's *A. granilabiatus* but do not show papillae nor muscle spot. Besides, the convexity of the ventral margin is less prominent. The slight overlap of the right valve over the left valve along the ventral margin is thin and could be weathered or worn away so easily that it might not show on poorly preserved specimens. *Aparchites arrectus* Ulrich may belong to this species too and represent a younger instar of *A. millepunctatus*, but more detailed investigation is necessary. The dispersion range is about ten.

Locality.—All specimens were obtained from the rock quarry of the Medusa Portland Cement Company, about three miles northeast of Dixon, Illinois. The material



TEXT-FIG. 3—Four distribution charts of the living freshwater ostracode *Cyclocypris ovum* cf. *sharpei*.

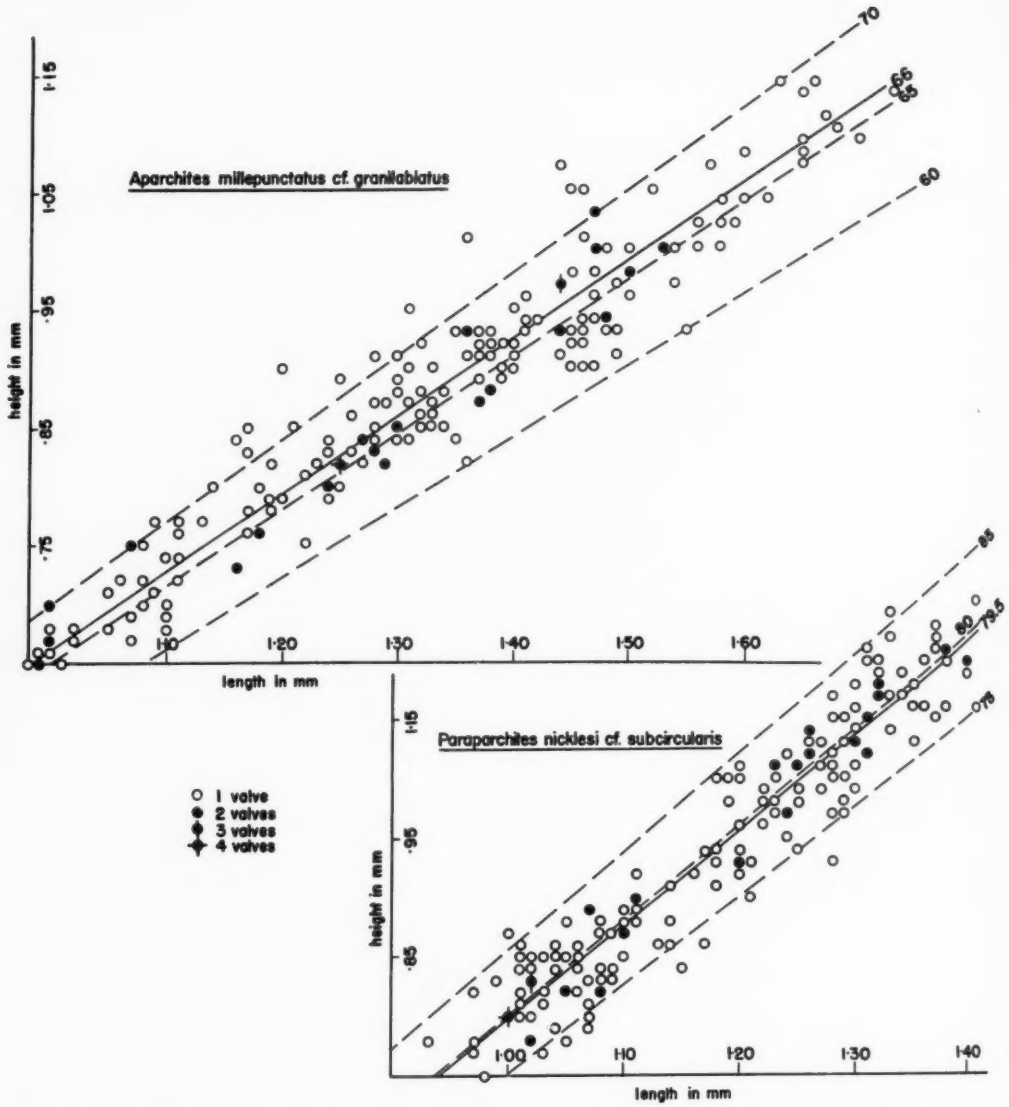
was washed from a weathered shale dumped within the quarry. The sample was collected and prepared by R. C. Gutschick. The section exposed in the quarry is Middle Ordovician Platteville group, Mifflin formation.

PARAPARCHITES NICKLESI (Ulrich), 1892
cf. P. SUBCIRCULARIS Geis, 1932

Morey described *P. nicklesi* from the Amsden formation of Wyoming (1935) and from the Mississippian of Missouri (1935). His illustrations match *Paraparchites subcircularis* Geis—closely as well as those of *P. nicklesi* from the Clore limestone of Illinois (Coryell & Johnson, 1939). The "roundness" (height-length index) in these three occurrences is 78, 82, and 82—very close to the average index of author's specimens. The nearly straight dorsal margin of the left valve in *P. nicklesi* can also be observed.

Morey's description of *P. nicklesi* of the Chouteau formation of Missouri (1936), Harlton's *P. nicklesi* of the Fayetteville shale of Arkansas (1929) and Cooper's specimens from the Chester and the "upper Kinkaid" of Illinois (1941, 1947) show a greater elongation of the valves than the previously mentioned forms from the Amsden, Clore, and Chouteau. Their indices average about 71 and extend as low as 67. These longer specimens are nearly identical with *P. carbonarius* (Hall) as described by Geis (1932).

Discussion of species.—The obvious break of the dispersion along the abscissa at the length of 1.15 mm. apparently marks the line of separation of the adult specimens



TEXT-FIG. 4—Distribution charts of the Ordovician ostracode *Aparchites millepunctatus* cf. *granilabiatus* and of the Mississippian ostracode *Paraparchites nicklesi* cf. *subcircularis*.

with an earlier instar or instars (Text-fig. 4). The author believes that *P. subcircularis* Geis and part of the round *P. nicklesi* belong to one species. The longer *P. nicklesi*, however, should be referred to *P. carbonarius*.

Locality.—Old Cleveland quarry, highest section exposed. One mile northwest of Harradsburg, Indiana. Geis secured part of his material from the same locality.

CONCLUSIONS

Three different living and two fossil species give evidence of quite a diversity in specific variation. Although, it would be erroneous to compare three Recent freshwater ostracodes from temporary ponds with the fossil marine ostracodes of unknown life cycle, there are some resemblances.

Living ostracodes.—The comparison of the

dispersion ranges in the following summary indicates the lowest figure for *Cyprinotus incongruens* and the highest with the two fossil species.

Cyprinotus incongruens	6–7
Cypria turneri	7–9
Cyclocypris ovum cf. *sharpei*	8–9
Aparchites millepunctatus	10
Paraparchites nicklesi	10

If the ostracodes for measurement had been supplied from a brood in an aquarium, the dispersion range would possibly have been similar to that achieved from some natural pond. Loosanoff (1954) bred the clam *Anomia simplex* from the egg and observed striking differences in both the sizes of the larvae and their growth speed, including those from the same parents under identical conditions in the same culture jar. The differential growth rate observed in the clams is applicable to any population of invertebrates, according to Loosanoff. This generalization includes ostracode populations in small ponds, nature's aquaria, and results in the coexistence of various instars. Slobodkin (1954) attributes the inevitable fluctuations to certain frequencies which are selected out of a combination of varying environmental variables.

In addition to the dispersion of the population it appears that *Cyprinotus incongruens* increases its dispersion range just before the species disappears late in spring. Additional investigations would be required to confirm this observation, however.

Fossil ostracodes.—The diagrams of *Aparchites millepunctatus* and *Paraparchites nicklesi* resemble the living material, however the dispersion range is larger. This fact is not surprising for the samples were not taken from just a single thin layer of shale. If we consider that a few inches of shale or limestone may represent a time of deposition of more than a thousand years, numerous minor and even major environmental changes are likely to arise. If there were seasons in the Ordovician and Mississippian periods, changes of seasonally limited ostracodes could have occurred in the same way that they are observed in *Cyprinotus incongruens*. A large variability in the fossil population should be expected.

Acknowledgment.—Special thanks are due to R. C. Gutschick for criticism and helpful suggestions in the preparation of this paper.

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FATUOUS SPECIES AND HYBRID POPULATIONS

J. MARVIN WELLER
University of Chicago

INTRODUCTION

Many invertebrate paleontologists recognize the limitations of old-style descriptive paleontology and some are attempting to break away from it. Efforts are being made to apply modern biologic principles to the study of fossils and thus learn more about them as creatures that once were dynamically alive and adjusted to their environments just as similar modern creatures are. The importance of such studies with respect to both pure and applied paleontology is obvious. One cannot expect all paleontologists to view these efforts with equal concern or to progress in the same direction, and perhaps it would be undesirable for them to do so. Nevertheless, the appearance of reports which misapply biologic principles should be the source of disappointment and regret to all, especially if they are issued by old and respected institutions. Such a publication is "The pyramidellid mollusks of the Pliocene deposits of North St. Petersburg, Florida" by Paul Bartsch (Smiths. Misc. Coll., vol. 125, no. 2, 1955, 102 pp., 18 pls.). This report is devoted exclusively to the minute taxonomic splitting of a group of closely related gastropods with total disregard for the significance of the differences noted. It is an example of old-style paleontology carried to extremes.

Little useful service would be performed by a critical review of this work as many of its shortcomings will be obvious to any careful reader. It should not be permitted to pass without some notice, however, for two reasons. First, vigorous protest should be registered against the type of species-making that it exemplifies and, second, American students and paleontologists abroad should be warned that it is not to be accepted as an approved example of modern paleontologic studies in this country. Also it provides an opportunity to discuss the art of species-making that, in invertebrate paleontology at least, is often practiced unscientifically.

ART OF SPECIES-MAKING

Minute taxonomic discrimination at a specific or lower level is justified if the resulting groups can be demonstrated to have biologic, geographic or stratigraphic significance. The rank properly accorded to such groups, whether specific, subspecific, or racial, may be very difficult to determine for fossils, and each instance poses individual problems which need not be considered here. Biologic significance may be revealed by statistical analysis if adequate population samples are studied. Geographic and stratigraphic significance may be demonstrated if enough adequately distributed specimens are available. In each case a considerable number of specimens is necessary to establish such groups on a sound foundation. Often, in paleontology, specimens are not adequate, and their lack must be compensated by the experience and judgment of the paleontologist. Under such circumstances trivial differentiation may appear to be reasonable; however, it is based on opinion rather than on solid evidence. The groups distinguished should be recognized as being subjective and provisional, though a large proportion of paleontologic species are of this type.

The fact that so many paleontologic species are subjective, in the sense indicated above, demonstrates that paleontologic species-making is more generally an art than it is a scientific occupation. Like other arts, this branch of paleontology, encompasses the activities of both good and bad practitioners. The difference lies mainly in the various concepts held by different persons as to what constitutes a species and the restraint exercised in the differentiation and naming of presumed new species. The typological concept of species, so widely held by many paleontologists, is likely to result in overemphasis of morphological differences and neglect of the variability that occurs in every natural population. Species based upon this concept are un-

realistic biologically and are likely to lack significance. If carried to extremes, species defined by types become nonsensical.

Paleontologic species, like modern ones, should be recognized as natural groups of individuals that vary more or less among themselves. The range and limits of variability may be difficult to determine, but a species cannot be characterized realistically without this knowledge. A conscientious modern paleontologist will carefully consider the possibility of variation and with this in view, compare his specimens with previously described species before he proposes a new one. He will recognize that similarities must not be overlooked, and that they may be equally as important as differences.

Bartsch has described 113 species from North St. Petersburg, all but one of them as new. Of these, 39 are based upon a single specimen and 36 are based on only two. These constitute two-thirds of the entire fauna. Only five species are based on more than ten specimens. The average number of specimens per species is 3.7. More than three-fourths (87) of all species described are grouped under five genera or subgenera. *Pyrgiscus* has 24 species. In these groups the average number of specimens per species is 2.8. *Chrysallida* has 21 species each represented by an average of 1.7 specimens. The foregoing figures speak for themselves. Most of Bartsch's species are based on samples that are inadequate almost to the ultimate. Also most of the species referred to individual genera are so similar that comparison of descriptions and illustrations does not make taxonomic distinction clear. Descriptions are often long repetitions differing only by a few qualitative adjectives or phrases. Illustrations are all enlargements, but their scale is nowhere indicated and enlargement is not uniform. Illustrations of species in one genus (*Odostomia*) presented on a single plate (18) vary from ×7.25 to ×21.0, if dimensions given in the text are accurate. Finally, comparisons which might be more useful than extended descriptions are inadequate or omitted altogether. Where present, they generally refer to only the immediately preceding or immediately following species of the text. Only in one instance is comparison made with a species not described in the report although several thousand pyramidellid species are said to have been recognized previously (p. 5).

All of these facts demonstrate an extremely narrow typological approach to species-making. Bartsch has reduced this art to the status of little more than an intellectual exercise in close observation and minute discrimination almost entirely divorced from biologic reality. Should one believe, for example, that 24 different but very closely similar species of *Pyrgiscus* actually lived in intimate association with each other? The only conclusion that seems justified from the facts available is that most of these species, as well as most of those referred to other genera, are slightly different variants of a moderately variable population. Because they are presumed to have lived together they cannot justifiably be interpreted even as different subspecies or races. The creation of such a host of unwarranted species is a great disservice to paleontology as it has introduced practically meaningless names which must be considered, listed and cross-indexed by future paleontologists.

HYBRID POPULATIONS

The narrow typological definition of species gives rise to a special class of imaginary problems because it denies the possibility of any appreciable degree of variation within the supposed species. Any considerable number of similar but slightly different specimens must either be separated into distinct species, as Bartsch has done for *Chemnitzia*, *Mormula*, *Pyrgiscus*, *Chrysallida* and *Odostomia*, or a special explanation must be provided to account for the occurrence of a variable group which is necessarily considered to be unnatural. Thus, such variability has been interpreted as the distinguishing mark of a hybrid population.

Hybrids do occur in nature but they are relatively rare. The recognition of a hybrid population should be regarded by taxonomists as a caution signal; it is sure indication that the parent groups have not diverged greatly in genetic structure. The discovery of hybrids should be followed by the careful reassessment of the morphologic characters which serve to differentiate the parents and

of the taxonomic status accorded them. Any postulation of hybridization, without knowledge of the parents, is unrealistic and unscientific.

It should be obvious that a greater range of variability is likely to be apparent in a species represented by many individuals than in a species known from few. Bartsch considers this relation to be noteworthy and quotes from several previous publications but he views it in an inverse fashion. In one of them he wrote "Among the Pyramidellidae it seems to be the rule, that the most variable forms are the most abundant and most widely distributed" (p. 54). This, by implication at least, is a perfect example of "the cart before the horse." The observed range of variability is dependent upon abundance but not the reverse.

The practice of a narrow typologist serves to magnify the importance and unusual nature of a variable group represented by many specimens which Bartsch terms a "complex" considered to be in a "state of flux." Similar less well represented groups generally show gaps in the variable sequence which are used as the basis for separating species. Thus the real unity of such a group is hidden under several different names.

Among the Florida fossils, Bartsch recognized one variable group consisting of at least 60 specimens which he interpreted as a hybrid "complex" apparently because gaps in variability that might be used to separate species were not noted. The parents of these supposed hybrids are not known but, as the group combines features said to characterize two subgenera (p. 57), they are implied to be subgenerically distinct. If this were true, it presents a peculiar situation because numerous other species grouped together under other subgenera and, therefore, presumed to be more closely related than the supposed parents of this group, are evidently believed to have lived together without crossing. The evidence with respect to this variable group almost certainly has been misinterpreted. First, there is no real reason for concluding that it is hybrid. Second, the association of features characteristic of two subgenera strongly suggests that the importance of these features has been overemphasized. Probably these subgenera are no more significantly different at their taxonomic level than are most of the narrowly defined species.

Bartsch's whole approach to the problems of species, variability and hybridization runs counter to the most basic biologic principles. He has sacrificed principles to the most narrow kind of typological taxonomy. His appreciation of genetics also appears to be imperfect, because he regards the variable members of the supposed hybrid series as "mutants" (p. 57). Finally, his nomenclature is faulty for he proposed a formal name for a "pseudogenus" (hybrid group) whose members are likewise named as a "new species" (p. 57). The International Rules make no provision for such names and these are certain to cause trouble in the future.

The space devoted here to criticism of Bartsch's work is out of all proportion to its value. In illustrating certain features of paleontologic practice, however, an outstandingly poor example is likely to be more effective than a good one because its shortcomings are so glaring. Unfortunately, good practice, of which there are many examples, is likely to be taken for granted and accepted without the commendation which it deserves.

VARIABILITY

Variation within modern species is commonplace and has been observed by all. The most extreme examples occur among domesticated animals and plants where man has interfered with natural processes by selective breeding. Some remarkable examples, however, also occur in nature and should be recognized as indicating that, even among fossils, very wide limits of variation are possible. In this connection I have been greatly impressed by a group of modern Philippine nonmarine snails that I collected recently at Tinogboc on Semirara Island, Antique Province. These shells number more than 300 and have been identified as *Neritina* (*Vettoida*) *variegata* Lesson by Dr. Fritz Haas of the Chicago Natural History Museum. They constitute an extraordinary assemblage because of the wide and striking variability of color patterns which they present. Literally, no two specimens are alike. These shells show three simple end members which are solidly black, dark cherry red and pale buff respectively. These are connected

by specimens which vary in two quite distinctive ways. First, the black shells grade through speckled into striped ones. The black stripes extend transversely to the direction of whorl growth and are separated by buff, or more commonly white, interspaces. The stripes grade from very narrow to very wide and, in their simplest development, vary from vertical to strongly inclined downward and forward. These show gradations into very complexly zigzag stripes.

The other type of variation involves spiral bands of red, buff or more rarely white which vary in number and disposition. Some of these bands, most commonly the buff ones, carry segments of the black stripes that end abruptly above and below. The stripes are often chevron-like but vary greatly. The striped bands and colored bands do not always correspond. Many shells show abrupt changes in pattern at a line that marks an injury but others change similarly where there is no sign of breakage. Some of these patterns later revert to their original form. Many of the shells also show gradual changes in their patterns.

Observation of this entire lot of neritinas suggests that certain general features of the color patterns are genetically controlled. The dominant type is completely striped. The background colors are generally quite constant, whether solid or disposed in bands. The variability and changes in ornamentation of many specimens, however, are indication that other features of the patterns are not genetic but are related to changes in the mantle edge.

These shells also show great variability in other respects. The apical angle ranges between 71 and 124 degrees. Also, crenulations on the thickened inner lip are notably, but less conspicuously, variable.

These Philippine shells do not represent a hybrid population. The species is known throughout a wide geographic range on many islands, and the specific name reflects the variability in ornamentation which is characteristic.

Color patterns are not often preserved in fossils. However, there is no reason to believe that variability in this respect is less significant than variation in sculptural details, and many modern species are based on differences in color pattern. Even Bartsch has noted that the sculpture of some specimens is not constant (pp. 53, 55). Therefore, it also is unlikely that all sculptural details are genetically controlled. Such observations indicate that details of ornamentation in gastropods are not necessarily a satisfactory basis for specific differentiation. They should be used for this purpose with caution, and minute differences should not be relied upon in the absence of other evidence. Whereas variation can be expected to occur, its range within different species is likely to differ greatly and wide variation cannot be accepted as evidence of hybridization.

There is no easy way to evaluate the taxonomic significance of small morphologic differences. There is no substitute for the good judgment and restraint that should be exercised by every paleontologist.

UPPER DEVONIAN OSTRACODA: CORRECTIONS

LEE B. GIBSON
Creole Petroleum Corporation, Maracaibo, Venezuela

Dr. Stuart A. Levinson has kindly advised me that *Morrisites* Gibson, 1955 (Upper Devonian Ostracoda from the Cerro Gordo formation of Iowa: Bull. Amer. Paleont., vol. 35, no. 154, p. 21) is preoccupied by *Morrisites* Buckman, 1921 ("Type Ammonites," 3, pt. 28, p. 48).

Morrisitina Gibson, new name, is hereby proposed for *Morrisites* Gibson, 1955.

In early impressions of the same publication, the following errors have been noted: on page 16, under "Remarks," the reference to *Bairdia subtilla* Cooper should read *B. subtila* Cooper. On page 17, line 8, reference to *B. glennesis* Kellett (1935) should read *B. glennensis* Harlton (1927).

CORRECTION: TRIOPSIDAE KEILHACK, 1910, NOT TCHERNYSHEV, 1940

PAUL TASCH
University of Wichita, Wichita, Kansas

The notostracan family Triopsidae was incorrectly credited to the authorship of Tchernyshev (Jour. Paleontology, 1955, vol. 29, p. 553–554). The writer rectified this error too late to correct proof.

Ludwig Keilhack (1910, Zur Nomenklatur der deutschen Phyllopoden. Würzburg: Zoologische Ann. Band III: 177-184) established this name after indicating his belief that *Apus* Schaeffer was occupied. Accordingly, he restored *Triops* Shrank, 1803. Then, in order to embrace both *Leipidurus* Leach and *Triops* Shrank, he set up the family Triopsidae (new name Keilhack, 1910, p. 182).

With the rejection of *Triops* Shrank (Tasch, 1955, p. 555–556), Apodidae Burmeister, 1846, replaces Triopsidae Keilhack, 1910.

A CASE OF PARALLELISM IN UPPER CRETACEOUS AMMONITES

OTTO HAAS
The American Museum of Natural History, New York

Haas & Simpson (1946, p. 340, footnote 61) record, and give an example of, homeomorphy between single structures.

Now *Acanthoceras athabascense* Warren & Stelck (1955, p. 71, pl. 6, fig. 5, 6; pl. 7, fig. 1, 3, 4; pl. 8, fig. 1–3; pl. 9, fig. 2) from the Labiche shale of Alberta develops, in maturity, latero-ventral horns (*op. cit.*, pl. 8, fig. 1, 3; pl. 9, fig. 2) which resemble those of *Collignoniceras* (="*Prionotropis*") *woollgari* Meek (? non Mantell), var. *alata* Haas, as illustrated by Meek (1876, pl. 6, fig. 2; pl. 7, fig. 1g) and by the writer (1946, text-fig. 19–22, pl. 18, fig. 2, 7, 9, right portion) to such a degree that these horns, as such, might be considered homeomorphic between one another.

This homeomorphy is, however, merely one between single structures and produced by parallel sculptural developments in *Acanthoceras* on the one hand and *Collignoniceras* on the other; the first genus belongs to the Acanthoceratidae, the second to the Collignoniceratidae. The two forms, themselves, are far from homeomorphic and can readily be distinguished in whorl profile; *A. athabascense* lacks, in maturity, the median keel which persists in *C. woollgari* var. *alata*, throughout development, and its intracostal section is characterized by nearly parallel flanks, whereas they markedly converge ventrad in the latter form.

The present case in here shown chiefly to point out the extreme caution that must be exercised in all inferences from a single structure, in this particular case from a sculptural element, to the whole of a fossil. Cuvier's principle of correlation of parts may well lead the incautious astray. I can readily imagine how a student thoroughly familiar with Cretaceous ammonites, upon picking up in the field a single horn of *A. athabascense*, like the one illustrated in fig. 2 of Warren & Stelck's pl. 9, may feel tempted to ascribe it to the var. *alata* of *C. woollgari*. In yielding to such temptation, he would not only arrive at an entirely wrong paleontological identification but also at an incorrect dating of the respective beds, the Labiche shale, which has yielded *A. athabascense*, being of Cenomanian age, whereas the Carlile shale, in which the var. *alata* of *C. woollgari* occurs, is Turonian in age.

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JOURNAL OF PALEONTOLOGY, VOL. 29, NO. 6, PP. 1072–1073, NOVEMBER 1955

REVIEWS

HANDBOOK OF OSTRACOD TAXONOMY, by Henry V. Howe. Louisiana State University Studies, Physical Science Series No. 1, (Baton Rouge, June 1955), pp. 1–386. Paper cover. Price $5.00.

This volume brings together for the first time the available data on the generic and suprageneric taxonomy of ostracods, including both fossil and living forms.

The first part of the handbook lists described ostracod genera and suprageneric categories, both fossil and living. Included are references to misspellings of generic names and suprageneric categories with their equivalent names, *nomina nuda*, homonyms, and synonyms. Following the generic name is the type species, author, date, page reference to the original generic description, synonymy (where synonymy was suggested, noting the author and reference), family affiliation and author (where a genus has been assigned to more than one family this also has been noted), and the stratigraphic and geographic occurrence as given by the original author (or the age assigned to the type species, in cases where the type species was described by an earlier author). Invalid generic names and suprageneric categories are underlined.

The second part of the handbook is an annotated bibliography of papers in which new genera and suprageneric categories are described, as well as other papers cited in the first part of the handbook. It is the most nearly complete bibliography on ostracod taxonomy ever to be published.

The third part of the handbook consists of a list of the serial publications containing works on ostracod taxonomy, giving the titles as they are listed in the Union list of serials (if they do not appear in the Union list, they conform with standard library listings). With each serial publication is given a list of authors of articles on taxonomy, with the dates of publication in the serial, which provides ostracod workers a guide to the importance of the various journals. Appended to the handbook are additional entries from seven papers which were recently received by the author.

A handbook of this type, bringing together information on the taxonomy of ostracods, has long been needed. Dr. Howe has found that many of the dates of references have been consistently incorrect, as have been the spellings of some generic names. A number of homonyms are noted for the first time in the handbook but, because this is an objective study, no new names are proposed. There are a few typographic misspellings, and in some cases invalid names in Part 1 are not underlined; however, such occurrences are few.

The reviewer believes that this handbook will greatly help the paleontologist to correct and standardize the taxonomy of ostracod genera and suprageneric categories and to bring genera previously unknown to the attention of ostracod workers. As it stands it should be an invaluable aid to the student as a reference to pages and figures of original descriptions and as a compilation of synonymy, and because it is so comprehensive, stimulate research in the field of Ostracoda.

STUART A. LEVINSON
Humble Oil & Refining Company
Houston, Texas

MICROPALEONTOLOGY, Amer. Mus. Nat. Hist., New York; Brooks F. Ellis and Angelina R. Messina, Editors.

The first issue of *Micropaleontology* was released in January 1955. The policy of this new quarterly journal, which replaces *The Micropaleontologist*, is to emphasize stratigraphic and applied micropaleontology and micropaleobotany and paleoecology rather than straight taxonomic papers. Faunal papers are not excluded, however, if they have stratigraphic significance. Articles pertaining to the living representatives of the various taxonomic groups and their ecology will also have an important place in the new journal. Papers will be published in any language using the Roman alphabet provided an abstract in English is included, and it is hoped that this policy will encourage workers outside of the United States to contribute articles to the quarterly.

The informality of *The Micropaleontologist* is preserved in the new publication. News items reviewing research activities

of paleontologists and micropaleobotanists from various parts of the world, which were a major part of the older journal, have been carried over to *Micropaleontology*. Also retained is the section, "Notes and Comments," which will include short papers pertaining to techniques of the trade.

Micropaleontology is edited by Brooks F. Ellis and Angelina R. Messina. There is also an editorial board of 19 workers who screen papers submitted for publication in the journal. The size of the quarterly is 8½ by 11 inches. Photographic illustrations are either collotype or 300 line half-tone reproductions. The current subscription is $5 per year; however, beginning with the January 1956 issue, the subscription price will be $8 per year. Manuscripts and correspondence pertaining to subscriptions should be sent to the Department of Micropaleontology, American Museum of Natural History, Central Park West at 79th Street, New York 24, New York.

STUART A. LEVINSON
Humble Oil & Refining Company
Houston, Texas

JOURNAL OF PALEONTOLOGY, VOL. 29, NO. 6, PP. 1074–1075, NOVEMBER 1955

NOTICES

REPRINT OF SHERBORN'S "AN INDEX TO THE GENERA AND SPECIES OF THE FORAMINIFERA"

The comprehensive *"An index to the genera and species of the Foraminifera,"* by Charles Davies Sherborn, originally published by the Smithsonian Institution in two parts in 1893 and 1896, is being reprinted, bound in cloth in one volume, 485 pages in length. Copies may be obtained from the Editorial and Publications Division, Smithsonian Institution, Washington 25, D. C., price $3.50.

Sherborn's index included all species described up to and including 1889. This important reference to the genera and species of the Foraminifera has long been out of print and unavailable to many foraminiferal students. Recently Hans Thalmann has completed for publication an index continuing the work of Sherborn from 1890 to 1950. Upon publication of Thalmann's work, which does not deal with species established prior to 1890, students of the Foraminifera will have available in these two publications a complete index up to 1950.

ALFRED R. LOEBLICH, JR.
U. S. National Museum

THE PALEONTOLOGICAL SOCIETY OF INDIA

With a view to organize and promote advanced studies and research in the field of paleontology and allied sciences including prehistoric archeology, for which there is such ample scope in this country, a "Paleontological Society of India" was founded in 1950, with Dr. M. R. Sahni, paleontologist, Geological Survey of India, as its first president. One of the main objectives of the Society is to initiate and encourage paleontological research throughout the country, with particular reference to its application in the economic field, especially petroleum exploration and coal prospecting. Attention will also be paid to the study of human paleontology in its relation to geochronology, based upon the study of the Pleistocene cultures of India. The Society will endeavor to organize a permanent field survey for expeditions to selected areas for the collection of material for research on special topics of pure and applied paleontology. Eventually, an all-India paleontological library and museum will be established. In pursuing these objectives, the Society has been able to enlist the enthusiastic encouragement and cooperation of a number of eminent scientists both in India and abroad, many of whom sent messages of goodwill and support.

An important part of the Society's activities will be the publication of a journal containing authoritative papers on paleontology and allied sciences, with special reference to India. Professor L. Rama Rao of Bangalore, former professor and head of the Department of Geology in the Mysore University, will be its chief editor. The inaugural number of the journal is in press and will be published shortly; it will contain more than 25 papers by leading workers from India, United Kingdom, United States, Europe, South Africa, Ceylon, and Australia, dealing with diverse aspects of current research. The journal will thus be of international status.

In cooperation with the existing scientific institutions in the country, the new "Paleontological Society" hopes to contribute to the general progress of scientific research in India. The Society has now the support of over one hundred fellows, including several eminent foreign paleontologists and others working in allied fields.

The officers of the Society, drawn from several Indian universities are: *President*, Dr. M. R. Sahni (Calcutta); *Vice presidents*, Professor L. Rama Rao (Bangalore) and Professor Rajnath (Banaras); *Secretary*, Professor S. R. Narayana Rao (Lucknow) to March 1954 and Shri J. P. Srivastava (Lucknow) thereafter; *Joint-Secretary*, Shri B. S. Tewari (Lucknow); *Treasurer*, Dr. R. C. Misra (Lucknow); *Council Members*,

Dr. M. R. Sahni (Calcutta), Professor Rajnath (Banaras), Professor L. Rama Rao (Bangalore), Professor S. R. Narayana Rao (Lucknow), Dr. V. B. Shukla (Nagpur), Dr. R. C. Misra (Lucknow), Dr. G. W. Chiplonkar (Saugar), Shri Y. Nagappa (Digboi), Professor D. K. Chakravarthi (Banaras), Professor S. R. Kilpady (Nagpur), Dr. H. D. Sankalia (Poona), Dr. K. P. Rode (Udaipur), Shri B. B. Lal (New Delhi), Shri J. P. Srivastava (Lucknow), Shri B. S. Tewari (Lucknow).

The editorial board of the journal is composed of: *Chief Editor*, Professor L. Rama Rao; *Members*, Dr. M. R. Sahni, Professor S. R. Narayana Rao, Professor Rajnath, Shri B. B. Lal, and Professor D. K. Chakravarthi.

L. RAMA RAO
Bangalore, India

1954 BIBLIOGRAPHY AND INDEX OF FORAMINIFERA

The customary bibliography and index to new genera, species, and varieties of Foraminifera for the preceding year, by Hans E. Thalmann, will be included in a later issue of the Journal.

EDITORS

THE RESULTS OF THE RECENT S.E.P.M. ELECTION HAVE JUST BECOME AVAILABLE. The new officers of the Society are to be:

President: Robert R. Shrock, Massachusetts Institute of Technology, Cambridge

Vice-President: R. V. Hollingsworth, Paleontological Laboratory, Midland, Texas

Secretary-Treasurer: Samuel P. Ellison, Jr., University of Texas, Austin

Editor: W. M. Furnish, State University of Iowa, Iowa City

JOURNAL OF PALEONTOLOGY, VOL. 29, NO. 6, PP. 1076–1077, NOVEMBER 1955

SOCIETY RECORDS AND ACTIVITIES

ACKNOWLEDGMENT

The Society acknowledges, with thanks, the receipt of $884.28 from the New York Oil Finders Convention Committee. This gift was made possible because the following contributors to the Guarantors' Fund generously left their contribution in the convention funds.

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THE FOLLOWING OFFICERS OF THE S.E.P.M. GULF COAST SECTION WERE INSTALLED OCTOBER 13, 1955

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Vice-President: F. S. Westmoreland, Atlantic Refining Co., Box 1346, Houston, Texas
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Treasurer: Eleanor Caldwell, Humble Oil and Refining Co., Box 506, Tallahassee, Florida

ANNOUNCEMENT OF ANNUAL MEETINGS CONRAD HILTON HOTEL

CHICAGO, ILL., APRIL 23–26, 1956

AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS SOCIETY OF ECONOMIC PALEONTOLOGISTS AND MINERALOGISTS

The 1956 Annual Meetings of the two petroleum exploration groups will be held in the Conrad Hilton Hotel, Chicago, Illinois, April 23–26, 1956. The executive committee of the A.A.P.G. is in charge of arrangements.

M. M. Leighton, Chief Emeritus of the Illinois State Geological Survey, will serve as General Chairman of the meeting. He has completed preliminary organization of the convention. J. Marvin Weller of the University of Chicago is General Vice-Chairman for the A.A.P.G., and Edward C. Dapples of Northwestern University, Evanston, Ill., is Vice-Chairman for S.E.P.M. Other members of the Central Committee are Laurence L. Sloss of Northwestern University, and Robert H. Dott and Elmer W. Ellsworth of A.A.P.G. Headquarters, Tulsa.

Technical Program: Laurence L. Sloss will serve as Technical Program Chairman for the A.A.P.G. The general theme of the program will be *Sealing Factors in Oil and Gas Reservoirs*, and will include a series of sessions and panel discussions dealing with the many factors which operate to halt the subsurface migration of oil and gas, or to place a seal on commercial pools.

A subsidiary theme to be pursued is *Possible Future Exploration Methods and Con-*

cepts; this will be developed by papers on methods, concepts, or techniques not necessarily in use now, but having potential value for the future of oil exploration.

The S.E.P.M. program is under the chairmanship of Robert R. Shrock of Massachusetts Institute of Technology, Cambridge, Mass. It will include sessions on sedimentary and stratigraphic problems, the porosity and permeability of carbonate rocks, a symposium on *Directional Properties of Sedimentary Rocks,* and a symposium of *Paleoecology.*

Entertainment: An interesting program of entertainment for delegates and their wives is being arranged by the Entertainment Committee. Clarence E. Brehm, independent oil producer of Mt. Vernon, Ill., is Chairman. The convention entertainment will be climaxed by the annual dinner-dance and floor show in the Grand Ballroom of the Conrad Hilton on Wednesday evening, April 25. Mrs. W. C. Krumbein, of Winnetka, Ill., is arranging an attractive program of entertainment for the ladies. This will include a fashion show, sightseeing tours, and visits to Chicago's famous museums and art galleries. A Ladies Hospitality Center will be maintained throughout the convention in the hotel's Astoria Ballroom.

Other Features: An unusual and interesting feature of the 1956 meeting will be the display and final selection of the winning designs in the nationwide contest for an official A.A.P.G. insigne and emblem. The contest closed on December 1, 1955, and preliminary judging of entries is now under way to select the best designs for final display in Chicago. A first prize of $50 and a second prize of $25 will be awarded the two best entries.

Again in 1956, a major attraction of the annual meetings will be the Employment Interview Bureau. Paul A. Witherspoon, Jr., of the Illinois State Geological Survey, is Chairman of the committee in charge. The Bureau will be in operation throughout the meeting and will bring students and others seeking employment in geology and geophysics into contact with employers' representatives from all parts of the country.

Exhibits: In addition to the technical sessions, entertainment, and other attractions, delegates to the 1956 convention will find a brilliant array of the latest tools and equipment used in oil exploration. There will be more than 12,000 square feet of commercial and educational exhibits, including geophysical equipment and supplies, drilling and well-servicing equipment, geologic field and laboratory equipment, technical books, and maps. Educational exhibits will be presented by the various geological surveys, societies, and university geology departments.

Housing: The Conrad Hilton Hotel is conveniently located in downtown Chicago, and all convention facilities and activities will be headquartered there. Details of reservation arrangements and a housing accommodation reservation form were printed in the November *A.A.P.G. Bulletin.* In addition, an official convention announcement and a self-addressed postcard reservation form were mailed to the general membership of the A.A.P.G. and S.E.P.M. on November 25. Members are urged to submit their reservation requests as soon as possible.

It is important that those making room reservations, but later finding that they cannot attend, should notify their hotel without delay. This will help to improve the hotel "no show" record of this convention.

Special low-cost, dormitory-style housing is being provided for students in the Conrad Hilton. Requests for these accommodations must be submitted on special application forms. A copy of the form is available for each college or university department from Paul R. Shaffer, Chairman, Alumni Luncheons and Student Housing Committee, University of Illinois, Urbana, Ill.

FRANK J. GARDNER, *Chairman*
Publicity Committee

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